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DRYING OF VEGETABLES

SHELTERBELTS

EMPIRE PRODUCTION OF DRUGS—II

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SOME NOTES ON PASTURE RESEARCH IN SOUTH AFRICA

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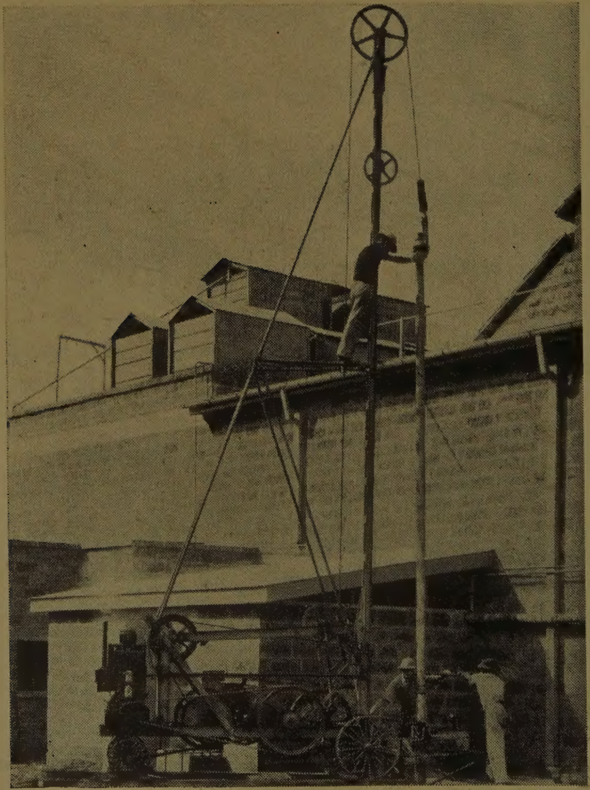

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FOREWORD

While it is doubtless still true that "an army marches on its belly" a modern addition might be that it sparks on its vitamins. Lack of them leads to general debility and makes its most spectacular appearances in the form of scurvy, beriberi and night-blindness. These deficiency diseases need especially to be guarded against when an army is operating in an inhospitable country and is dependent on preserved food. The needs of the East African campaign have stimulated research by the Kenya Department of Agriculture into methods of drying vegetables. The qualities required of the product were not easy to meet. It had to be palatable, of good appearance and to have retained its vitamins through the drying process. The means by which a satisfactory result was obtained are described in this number. Since also in peace-time there are many parts of East Africa where dried vegetables would be acceptable, it is hoped that a permanent industry might be built up.

A consideration of the five major entomological scourges of Africa—mosquitoes, locusts, termites, weevils, and tsetse-flies—leaves one in little doubt but that the last-named is probably the greatest curse of them all, for the reason that it renders no less than two-thirds of tropical Africa unproductive or even uninhabitable. It is not surprising therefore that so much effort and money has been spent on tsetse research in East Africa. The outstanding result of this work has been the demonstration that the tsetse-fly can be controlled over large areas by modifying the vegetation so as to reduce the factors essential for tsetse to below the minimum necessary for the fly's existence. The methods used in East Africa to bring about this control necessitate the clearing of trees and bush over extensive areas, which results not only in the elimination of the tsetse but in the improvement of grass growth. If then grazing is uncontrolled, overstocking and erosion soon follow, so that unless the areas reclaimed from the tsetse-fly can be protected from misuse, tsetse reclamation may defeat its own ends. We publish in this number two complementary articles on this complicated relationship between agricultural development and tsetse reclamation. The latter must be regarded as a necessary agricultural measure if mixed farming is ever to be started in what is now tsetse country. We commend these two articles to all those who are interested in the agricultural development of Africa. They will encourage those who are inclined to take a depressing view of the tsetse position and to question the value of tsetse and pasture research.

Another article in this number, "Shelterbelts" by Mr. G. H. Warren, provides a notable contribution to the long-term improvement of land-use in East Africa. In a large proportion of the whole area drought is an ever-present enemy to a permanent agricultural system. Any expedient that tends to conserve such moisture as the ground does receive should be considered. Since evaporation both directly dries the soil and puts a strain on the water system of the crop-plant, and since the degree of evaporation depends largely on wind velocity, a windbreak should have a doubly beneficial effect on cultivation in its lee. In the absence of any published experiments on the subject in East Africa, Mr. Warren draws largely on data from agricultural stations in the Russian steppes, recorded in a language that unfortunately closes this great bulk of investigational literature to most students. He also quotes American records and supplements them with the results of experiments which he has carried out himself with simple apparatus in a Kenya locality at 4,700 feet. It is very desirable that more observations should be made locally in the same way; but meanwhile it seems certain that the benefits of a shelterbelt of trees fully justify their planting, quite apart from their intrinsic value. A shelterbelt of *Cupressus macrocarpus* (which turns out to be much more effective than Eucalyptus) only 18 feet high, was found to reduce the evaporation to leeward so that even 90 feet from the trees it was 24 per cent less than that normal in the area. Mr. Warren concludes by giving practical hints on the actual planting of the shelterbelt and compares for this purpose the claims of the often neglected native tree species.

It will be recalled that in introducing in the January number of the Journal the subject of Empire drug production, reference was made to statements published in the United Kingdom regarding the drugs that were needed. Since then equally authoritative statements have been made that are not altogether in accord with the first. Special efforts are being made to obtain from London a specific pronouncement that will serve as a real guide to drug production in East Africa.

Meanwhile, for the second article in the series, camphor has been chosen as subject; while there is no likelihood that camphor planted now would come into production to meet war needs, the tree has special claims to esteem as a several-purpose crop which can be utilized and modified as the markets serve.

Tea, which has hitherto received little attention in the Journal, is dealt with in this number in a valuable article by Mr. A. S. Thomas, "Lessons from a tour of the tea districts of India." Though the Indian industry has many problems unsolved, it still has much to teach the comparatively young East African industry. Concerned with long-term prosperity of the local plantations, Mr. Thomas stresses the importance of planning the lay-out of an estate from the first, of starting it with good seed, of holding the soil and of the claims of shade.

CORRIGENDUM

Vol. 6, No. 4, p. 234, line 6: For the first word "plot" substitute "row".

SOIL MULCH AND MOISTURE CONSERVATION

Adapted from an article by L. L. Eksteen and M. J. van der Spuy in Farming in South Africa, *February,* 1941, *p.* 51

Formerly it was accepted without question that the loosening of the first few inches of surface soil by means of harrows or other implements was an aid to the conservation of the moisture in the lower soil. In spite of the fact that many findings during the past twenty years cast some doubt on the validity of this theory, there are still many farmers who believe in the effectiveness of a soil mulch in dry farming. The reason for this belief is partly due to the fact that the movement of moisture in the soil is not always correctly understood.

Capillary moisture such as appears in the soil can be divided into two types, viz. real capillary moisture and apparent capillary moisture. *Real capillary moisture* occurs in conjunction with underground water, i.e. within two or three feet above the level of underground water. In this zone the typical capillary movement of the moisture can be detected and may be compared with that of paraffin in the wick of a lamp. This upward movement can be inhibited by breaking the capillary tubes. In practice, therefore, the loss of this moisture as a result of evaporation on the surface can be reduced by cultivation, i.e. by establishing a mulch. It seldom occurs, however, that the natural level of underground water is only three feet below the surface of the soil.

If dry soil is irrigated and it is found after a while that the soil is moist to a depth of four feet, those four feet of surface soil are said to be saturated to their "field water capacity". The movement of moisture to the drier subsoil takes place very slowly, since this type of moisture, which is also known as *apparent capillary moisture,* moves mainly in the form of vapour. The same applies to the movement of moisture from below to surface soil already desiccated. A breakdown in the capillary tubes in the soil caused, for example, by cultivation can therefore have only a slight practical effect, if any, on the conservation of this form of moisture in the soil.

Recent experiments on heavy, clayey soil at the College of Agriculture, Glen, South Africa, have confirmed the conclusion reached from others on light, sandy soil, namely that cultivation is of much more value to a crop *as a means of controlling competing weeds* than as a means of maintaining a mulch for moisture conservation.

DRYING OF VEGETABLES

By V. A. Beckley, M.C., M.A., and Violet E. Notley, Chemical Section, Department of Agriculture, Kenya

The transport of fresh vegetables to troops in the forward areas of Eastern Africa is an almost insuperable problem. Fresh vegetables are bulky and rapidly deteriorate, especially when roughly handled, as certainly they would be on the rough roads of the hitherto roadless zones. Canned vegetables get over the difficulty of spoilage, but they too are very bulky; a ton of fresh cabbage after canning weighs 4,500 lb. The production of dried vegetables in Kenya as a food supply for the troops was given us as a problem for immediate solution.

The importance of dehydration is amply shown when figures are studied. A ton of cabbage as received after preparataion and dehydration weighs a little over 200 lb., occupies a bulk of about 4 cu. ft., and is not sensitive to rough handling.

The only information at our disposal was contained in a book published in 1920 describing the methods of dehydration employed in production of the dried vegetables issued as rations in the last war. Those of us who experienced these vegetables know they left great room for improvement, so it was necessary to start from the beginning. Perhaps a certain amount of time has been lost, but on the whole it is much to be doubted that this time has been wasted.

When the problem was first propounded the idea was to produce dried vegetables for the use of native troops only. Cowpea leaves form a staple item of diet amongst the local natives. Cowpeas grow readily and give heavy yields, so the first experiments were made on this material. Both sun-drying and artificial drying were tried. The former method was found to be very destructive of ascorbic acid (Vitamin C). As one of the main reasons for the use of vegetables in the rations for the troops is to prevent scurvy, it was very evident that it was no use pursuing the idea of sun-drying. Both sun-dried and artificially dried cowpea leaves were tested for palatability on the native staff at the Scott Agricultural Laboratories. The report was that it was quite good, but full of hard fibre. Apparently drying had so dehydrated the vascular fibres that they would not soften on cooking, thus spoiling the material. Another possibility followed was that of dried lucerne leaves. Lucerne is used as a green vegetable for native labour by the South African goldmines, so it appeared that here was a simple and cheap solution of the problem of the supply of dried vegetables. Both sun-dried and artificially dried lucerne leaves had a high ascorbic acid content, but it was found that the dried lucerne caused digestive troubles, so again we had to abandon this line of work and switch over to normal European vegetables.

In the early stages the main problem was to ascertain the most suitable temperature for drying, the rate of loading the trays so as to combine speed of drying with economic working, the two criteria being the palatability and the ascorbic acid content of the product. It is difficult to say which of these criteria should be considered the more important. A highly palatable product with a low ascorbic acid content would be of little use as an antiscorbutic, while a distasteful product of a high ascorbic acid content would also be of little value; troops would refuse to eat it. In our work we have taken both into consideration, combining palatability with ascorbic acid content, as will be seen in the discussion on cabbage.

It was found possible to dry practically any vegetable, though some in our opinion were far from suitable. Vegetables which contain much stalk are, after drying, liable to become very fibrous. Cowpea leaves, certain types of spinach, and most kales fall into this class. There is another danger in connexion with spinach; the temperatures encountered during drying were highly suited to the development of the organism *Clostridium botulinum*, which is responsible for the very dangerous form of food poisoning known as botulism. Very careful preliminary treatment would be needed to remove the danger. Tomatoes appear to be dried as a normal practice in Italy, but the material is most unappetizing in appearance, being black. All cucurbits, such as pumpkin, can be readily dried, but is it worth while drying pumpkins for use as a vegetable? In the United States of America pumpkins are regularly dried and to-day constitute perhaps the main dried vegetable produced there, but the dried pumpkin is practically all used for the making of pumpkin pies out of the "pie plant" season.

The vegetables it has been decided to dehydrate in Kenya are potatoes, cabbage, cauliflower, French beans and carrots. This does not exhaust the list of those suitable; many have been left out on account of disease or of pests. Turnips, for example, are highly suitable for dehydration, but are so badly attacked by certain insect pests that it has been decided not to touch them.

In the early stages of the work it was thought that pyrethrum driers would be suitable; so they are, so long as the scale of production is small. The scheme in Kenya has expanded until to-day our present estimates are of the order of over 30 tons of dried vegetables per week. The type of drier that is being installed at the factory is the Oregon type of tunnel drier, a single unit of which is capable of putting out between 1 and 1½ tons of dried cabbage daily. There would, however, be no reason why, for his own use, the pyrethrum grower should not utilize his drier for vegetable drying. Provided that suitable precautions are taken during preparation, prior to drying, the product will be of very good quality. All our work at the Scott Agricultural Laboratories has been done on a model pyrethrum drier.

Potatoes.—As potatoes contain very little ascorbic acid, our main aim has been to produce a material of good appearance and palatability. Potato flakes have for a very long time been an article of commerce, generally as a cattle food. They are prepared from cooked potatoes, dried on a rotating drum. If offered for human consumption they could only appear in a rather sloppy form of mashed potatoes, and we are very certain that troops would soon refuse to eat them. Something more is needed, a product that could be used in all the forms in which potatoes appear. Potatoes in the form of thick chips could appear as ordinary boiled, mashed or fried potatoes. This form, therefore, has been studied in our work.

When potato chips are dried the material becomes badly discoloured and does not take up water readily. It was very evident that in order to prevent the discoloration the enzymes responsible for it must be killed by heat, in other words "blanched". Our experiments on blanching gave us some most interesting results. If potato chips were steamed for a period of over a minute in live steam they dried nice and white, but if the steaming was for less than three minutes they failed to soften on cooking; one lot, steamed for two minutes and then dried, were not soft after soaking overnight and boiling for 2½ hours. When steamed for a minimum of three minutes a good-looking product was obtained. It was not white, but a pale yellow, translucent material, looking like horn. On soaking for two hours and boiling for thirty minutes these potatoes were indistinguishable from fresh. It was also possible to fry them after two hours' soaking.

Two samples of potatoes from one of our early large-scale experiments were sent to members of the forces for trial in the field. For our experiments we did not have all the facilities for blanching that we desired, and the appearance of the potatoes was not quite so good as it might have been. All the comments received agreed very closely. When soaked for the period we recommended the potatoes were rather dark in colour, but under field conditions were quite acceptable. If, however, they were soaked overnight before cooking they were excellent. One report states, "could not be distinguished from fresh potatoes".

On the factory scale the potatoes will be passed through a mechanical rotary washer, thence to a mechanical peeler, then cut up in a dicing machine into chips ⅜ in. square and about 1 in. long. As soon as possible the diced potatoes will be placed in a blanching machine, where they will be steamed for between three and four minutes, and then put under power sprays to remove the broken-down starch cells from the surface of the chips. They will then be entrayed and immediately put into the drier. The temperature in the drier is to be maintained at about 170° F., under which conditions drying will take about ten hours.

Cabbage is one of the most usual vegetables to be dried. The normal procedure is to blanch the shredded cabbage before drying. This was done originally to facilitate drying. Blanching, by killing the living plant cells, speeds up the rate of loss of moisture. Later it was learned that the main reason for blanching is to prevent the destruction of ascorbic acid. Experiments here show that dried cabbage blanched before drying has a much higher ascorbic acid content than that which has been dried without blanching. However, on continuing the experiments to include cooking, which is the true test, it was found that the blanched cabbage lost a far higher percentage of its ascorbic acid content to the cooking water than did the unblanched. As it is not usual to retain cabbage water for culinary purposes, the advantage is lost. In fact, in our experiments, the cooked unblanched cabbage had a higher content of ascorbic acid than the other. It is when we come to palatability that the real difference is seen. Palatability and attractive appearance play a very great part in deciding the suitability of the green vegetable as food. The cooked blanched material is a "mush," the green is dull and looks artificially coloured, the white parts are grey and most unattractive. In short, it looks like very badly prepared and overcooked cabbage. The cooked unblanched material, on the contrary, is crisp looking and is indistinguishable from fresh cabbage. For these reasons, cabbage will not be blanched, our conclusions being that blanching is not only unnecessary but deleterious.

Cooking experiments have been carried a good deal further. In our first experiments the dried cabbage was soaked for half an hour before being cooked. It appeared likely that under these conditions the enzyme responsible for the destruction of Vitamin C would be able to work actively, so an experiment was made of dropping the dried cabbage directly into boiling water. Treated thus, it required no longer cooking than after soaking. The appearance was that of fresh cabbage, but the best point was that the ascorbic acid content was twice that of cooked cabbage that had been soaked.

Samples of dried cabbage, also derived from our first large-scale experiment, were sent to men in the field. The reports received were enthusiastic. One sample had been travelling in the post close upon three months and had been all over Kenya, under all sorts of climatic conditions. When used it was found to be perfect.

In the normal procedure it is usual to remove the outer leaves and the core of a cabbage before cooking or drying. Investigations here have shown it is these parts which have the highest content of ascorbic acid. For this reason all the outer leaves that are not too coarse are to be retained. The core is to be shredded by special machinery, so that it too can be utilized. It may be thought that this may reduce the palatability, but this will not be the case. A great many of the outer leaves of the ordinary cabbage are very far from being coarse and harsh-flavoured. On drying they retain a very attractive green colour.

In the factory the cabbages will be examined, the coarse outer leaves removed, and then the head submitted to a high-pressure spray of water. The clean cabbages will pass to the core shredder, which breaks up the cores, and then to an American kraut-cutter, which shreds them into thin long pieces. This machine has a very large capacity, so that it will be possible to have the cut material transferred to the driers with a minimum waste of time.

Cauliflower.—As in cabbage, it was found that ascorbic acid is unevenly distributed in the cauliflower. The outer green leaves and the stalks of the inner flower have the highest content. Since the outer leaves of a cauliflower are not so coarse as those of cabbage, it is possible to use them to a greater extent. When dried they have a very good colour, which adds considerably to the appearance of the cooked product.

In our first experiments cauliflowers were dried directly after being cut into thin slices. Drying was found to be very slow and the product discoloured and unattractive. On soaking, however, it was quite attractive and closely resembled fresh material. In order to speed up the drying, experiments were made on blanching. This did help; again a period of three minutes was found to be required. The dried product was still rather unattractive in appearance, but rather better than the unblanched. But, on soaking and cooking, the blanched dried cauliflower is quite indistinguishable from fresh. Visitors to the Scott Agricultural Laboratories who have seen the blanched dried product and then seen it cooked pronounce it a conjuring trick.

In some of our experiments during drying, the cauliflower became infected by a bacterium which rapidly reduced it to an evil-smelling slime. Investigation showed that this was due to the early stages of drying being protracted. On raising the temperature in the drier from 130° F. to 160° F., the trouble was obviated, but even at this temperature, if drying is slowed down by overloading of the trays, the trouble recurs.

In the factory, cauliflowers, after removal of the more coarse outer leaves, will be cut into thin slices on a machine obtained for the purpose, passed to a steamer and thence to the trays. Here it is not necessary to place the material into the drier immediately, as there is no discoloration, but in order to reduce the possibility of infection the steamed cauliflower will be put into the driers as quickly as possible. In the tunnel-drier the greater part of the air is re-circulated, so it will be easy to deal with any chance infection by means of a little sulphur burnt at the air inlets.

French Beans.—Fairly young French beans, that is, those in which the strings have not yet developed, are suitable for drying on a large scale. When one has to deal with several tons per day it is quite impossible to string beans; an army would be needed. Such young beans are sliced and are then ready for drying. Blanching of beans prior to drying appears to be the general practice, but our investigations have shown that blanching is definitely deleterious. Unblanched beans contain, on drying, 50 per cent more ascorbic acid than do the blanched beans. In appearance, too, the effect of blanching is highly deleterious. Cooked unblanched dried beans have an attractive green colour, while the cooked blanched beans are brown. In taste there was no appreciable difference.

In the factory, procedure will be very simple. The beans will be machine-sliced, collected on trays and passed straight away to the drier. The drying temperature is 130° F. to 140° F.

Carrots are not to be regarded as a source of ascorbic acid. Their main function in the ration is to supply a change of food and at the same time a fair amount of Vitamin A. Again with carrots, the normal procedure seems to be to blanch them before drying. Our experiments, whether with carrots cut in slices or in strips, have shown that the sole effect of blanching is a loss in weight and a marked diminution of flavour. In the factory, carrots after being washed are passed to a table where the top will be removed and thence either to a machine where they will be cut in slices or to the dicing machine which will cut them into thin strips, and from either of these directly to the drier. The drying temperature will be 140° F. to 150° F.

A factory is being erected in the Kikuyu Native Reserve for the production of these dried vegetables on a large scale. Many criticisms have been made against the location of the factory in the native reserve. It has been suggested that their production is eminently suitable for the individual farmer. The description given above of the various processes that have to be employed with different vegetables will give some idea of the complexity of the whole thing. In this article we have not gone into detail to describe the various troubles that may occur, but the product from one of our large-scale experiments contained ten times more Vitamin C than did the material produced by a local farmer who wished to try the process. Somewhere he had made a mistake; perhaps overlooked some small detail of procedure which led to intense destruction of the most valuable Vitamin C. Using machinery that will enable the material to pass to the driers with the minimum waste of time obviates this danger.

When we come to the financial side of the whole process, the picture is not alluring. Very large scale production is needed at as low a cost as possible. For the war period dried vegetables from the Government factory are being sold to the Army at cost. When it is realized that the return of dried vegetables from the vegetables as received varies from 7½ per cent to just over 10 per cent, it is very evident that the price to be paid for fresh vegetables has to be low. The price being offered to the natives is one which is very fair and attractive to the native grower, but which would certainly not be so to a European farmer.

There is, however, one phase of the dried vegetable production in which it is possible for the individual European farmer to share. Although the dried vegetables contain a very fair proportion of Vitamin C, bad cooking can considerably reduce the quantity, and it is possible, even highly probable, that army cooks will be responsible for a considerable loss of Vitamin C in the ration, especially that of native troops. Also, men undergoing hardship or working very hard need a larger quantity of Vitamin C to prevent scurvy. Research has been going on in most of the laboratories in East Africa for something simple that will provide an adequate supply of ascorbic acid. In the course of his work on the ascorbic acid content of local fruits and vegetables, Dr. Jex-Blake assayed a specimen of a sweet pepper and found it contained a surprising amount of ascorbic acid. When the flesh was dried it was found to contain more ascorbic acid than any other natural product. It was the equivalent of some of the best concentrates. As a result of experiments conducted on native troops, it has been ascertained that all of them greatly appreciate the addition of a proportion of dried sweet pepper to their ration. It has therefore been decided by the medical authorities that the mixed vegetable ration for native troops is to contain 5 per cent of dried sweet pepper. Arrangements have been made for an adequate supply for this year. More will be required next year.

The method of packing is an item which calls for a good deal of consideration. Quite early it was decided to compress the dried material into blocks of 20 to 40 lb. each, and it was hoped that packing such blocks in paper-lined sisal bags would be sufficient. But it has been found that the unblanched dried material was apt to pick up moisture and then develop a most peculiar odour; tobacco-like is perhaps the best description. This odour did not affect palatability but it certainly is not attractive. Fortunately, it has been possible to secure sacks lined with bituminized paper which is moisture- and air-proof. These bags will completely solve the problem of safe transport.

Meanwhile experiments are being conducted to determine the rate of the destruction of ascorbic acid during storage of the dried vegetables.

Although this work has been instituted primarily as a wartime measure, there appears no reason why the factory should not continue to produce, perhaps on a smaller scale, after the demands of the Army have ceased. There are many parts of East Africa where it is often impossible to obtain fresh vegetables; really good dried vegetables would prove most acceptable. Not only would there be a market in East Africa but many parts of the East would be open to supply. Of course, the price that would have to be made would be considerably higher than that being made to the Army; but at even double the price, it would provide a cheap substitute for fresh vegetables where these cannot be obtained locally, and solve many a problem in catering.

Note

The scientific results of these investigations will be published elsewhere.

We are obliged to Dr. Nattrass, the Senior Plant Pathologist, for the pathological work connected with the cauliflower investigations.

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NEW USES FOR MAIZE

Of especial interest to Queensland maize-growers is the news that the United States Department of Agriculture is about to open a laboratory for the study of maize as an aid to industry associated with national defence. This will really be an extension of the work of investigation into the many industrial uses to which maize can be put, apart altogether from its uses as food for man and beast. It is proposed to explore the possibilities of maize as a base for synthetic rubber, plastics, fibres, and motor fuel. Last year, yarn, buttons, poker chips, and laminated boards made from a maize by-product were exhibited at the National Farm Chemurgic Conference, hence the possibilities sought by the research workers are not so very remote.

The by-product from which the articles mentioned are manufactured is a protein called zein, which constitutes about 10 per cent of the whole maize. Its most practical use at present is for coating paper. It is oil and grease proof. Zein films are tasteless, odourless, and non-toxic, hence they are useful for food containers. Another use is in solid colour printing using aniline dyes. It is claimed that by using zein, fugitive dyes can be made more light-resistant, and that bleeding dyes can be made more resistant to water. In a clear state, zein can be formulated to carry bronze and aluminium powders. It is also made into a plaster which can be moulded in combination with other resins. It has several other industrial uses which suggest the immense possibilities of a crop which is now so largely used as a food for farm animals.

The results of the research work now in progress will be awaited with interest, especially by those who foresee the effect these new developments must have on the future of our primary industries.

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SHELTERBELTS

By G. H. Warren, Kingolwira Estate

Shelterbelts is the term usually applied to plantations of trees arranged so as to protect fields and crops against unsuitable climatic conditions; they are sometimes referred to as "windbreaks" but the functions of such plantations extend, in many countries, far beyond the mere reduction of wind velocities.

Elsewhere, under conditions that—for part of the year at any rate—approximate to those found in the settled area of East Africa, it has been found that crop yields in areas protected by shelterbelts are heavier than those grown in the open; it is possible therefore that it might be helpful to farmers and planters in East Africa to examine agricultural conditions in those countries that have made the greatest use of shelterbelts, and to inquire into the reasons which led to the plantings and the results obtained where comparative data are available.

The countries in which the greatest use is made of shelterbelts are South-East Russia (the Eastern Ukraine), the Great Plains region of the U.S.A., Hungary, and Ceylon. The Dutch East Indies ought to be included, particularly Java, but it is not proposed to deal with them as so little data are available to the general public, or even to the foreign research worker.

In South-East Russia, then, there is a vast area which, from the agricultural point of view, can be described as "marginal"; when there is sufficient rain, an economic crop is got, but more often than not the crop in the open steppe does not yield an adequate return for the labour spent on it. The country is flat, altitude is from near sea-level to 500 feet; climate is sub-humid and meso-thermal, and subject to sharp changes of temperature; precipitation is adequate to deficient (21 to 8 inches), and hot winds with a relative humidity as low as 10 per cent sweep across the steppe, especially in spring. Evaporation is therefore high, and the precipitation-evaporation ratio is less than unity, varying from 0.97 in the north to 0.33 in the south. The typical soils of the region are the "Chernozem" soils; they have an alkaline reaction and are not suited to tree growth. This does not present a promising picture from the agricultural point of view. (It may be noted that these conditions approximate closely to those found in the "Dust Bowl" in the Great Plains region of the U.S.A.)

The Russian reply to this is a programme of 865,000 acres of shelterbelts—about 74,000 square miles—in five years. This programme was commenced in 1933, and was based on results obtained in the preceding hundred years. So far as is known, the first shelterbelts were planted by German immigrants in the Crimea in 1800, and the favourable results obtained were published in 1833.

Large-scale projects began to develop about 1880 and in 1891, following a disastrous drought, the Russian Government took action, a Commission commencing planting on a large scale. This was the origin of the present experimental stations at Derkul, Kamennaya and Mariupol, all of which are in the basin of the River Don. The objects in view were:—

(1) Protection of farms from wind.
(2) Aid in ripening grain.
(3) Reduction of evaporation.
(4) Retention of snow.
(5) Rise in the water table.
(6) Decrease in the range of temperature fluctuations.
(7) Attraction of rain.
(8) Increase in the productivity of waste unused lands.
(9) Control of soil erosion.

In 1893, a study of shelterbelt effects by A. A. Bychikhin[1] aroused great interest; it showed clearly the resultant decrease in wind velocities, the increase in soil moisture, and the increased grain yields in the sheltered fields. Subsequent published results[2] from experimental stations confirmed the earlier figures. Some statistics from Kamennaya are given in Table I.

As might be expected from these figures, it is found that 1921 was a dry year—a year of semi-drought—but there was enough moisture to ripen the crop; it is under such conditions that shelterbelt cultivation shows to the greatest advantage. 1922 was an exceptionally wet year; the advantages of shelterbelt cultivation are not so marked. Occasionally the crop within

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[1] Bychikhin, A. A.—"Znachenie Zashchitnykh Nasazhdenii dlia Stepnoi Polosy." (The importance of Forest protective stands to the Steppe region.) Odessa, 1893.

[2] Nauchno-Melioratsionnyi Institut.—"Lesomelioratsiya I Borba S Zasukhoi Na Iugovostoke." (The Forest Melioration and the Struggle against the Drought on South East Russia.) Leningrad, 1926.
Danilov, E. A.—"Zashchitnye Lesnye Polosy." (Protective Forest Belts.) Moscow, 1931.

TABLE I

CROP	Year	YIELD PER ACRE		
		Shelter-belt protection	Open steppe	Increase percentage on protected fields
		Tons	*Tons*	
Winter rye				
Grain ..	1921	0·388	0·101	284·2
Straw ..		0·716	0·247	189·9
Grain ..	1922	0·756	0·635	19·1
Straw ..		2·085	1·630	27·9
Grain ..	1923	0·414	0·254	63·0
Straw ..		1·137	0·826	37·7

the sheltered area is less than that in the open, as was the case at Kamennaya in 1918 (although the figures are suspect owing to local political disturbances). 1923 was an average year, and gives a fair idea of the advantages which may be expected from shelterbelts.

Grasses, and particularly alfalfa, are greatly benefited by shelterbelts, as at Kamennaya (Table II).

TABLE II

CROP	Year	YIELD PER ACRE		
		Shelter-belt protection	Open steppe	Increase percentage on protected fields
		Tons	*Tons*	
Alfalfa ..	1919	1·243	0·497	150·1
	1920	1·325	0·414	220·0
	1921	1·097	0·290	271·4

Again the increase in shelter is greatest in the driest year.

Some Russian experimental stations publish their figures as averages over a number of years, as they contend that this gives more reliable data than figures of individual years, a contention which is supported by American observers. Table III gives the figures from Saratov:—

TABLE III

CROP	Year	YIELD PER ACRE		
		Shelter-belt protection	Open steppe	Increase percentage on protected fields
		Tons	*Tons*	
Alfalfa..	1918-22	2·094	0·992	111·1

It seems worth noting that there is some variation in the reaction of various crops to shelter; the maximum yield of rye and hay is found immediately to leeward of the shelterbelts, but the yield of oats increases up to 200 feet to leeward of shelter, and thereafter decreases. The maximum effective height of the shelterbelt in question is about 54 feet, and its age 35 years.

This raises the question of the distance to leeward over which shelterbelts give protection, and widely differing figures have been given by different investigators; the main factor is the height of the belt, and in Denmark the distance over which protection extends is given as from 10 to 12 times the height. Some Russian observers put the figure at 20 to 30 times the height, and at Mariupol elaborate investigations by N. P. Leontievesky[1] put this figure at 2½ times the square of the height. If this formula is correct it would account for many of the puzzling discrepancies revealed when it was attempted to express the extent of the protected area as a function of the height of the trees.

It will be noted that the rate of growth of trees in Russia is very slow compared with East Africa. Oak (*Quercus robur* L.), which is the key species of many Russian shelterbelts, makes about 15 inches per annum. Compare this with *Muringa* (*Cordia Holstii*), which makes 50 inches per annum for the first eight years under average suitable conditions.

With regard to the objects in view when the Russian shelterbelts were planted, it is agreed that (1) and (2) have been achieved. In respect of (3), decreasing evaporation, there is no doubt that this has been successful in Russia and elsewhere. Table IV gives figures from Kamennaya; they are a seven years' average, 1918-24; the months taken are those in which temperatures, etc., approximate most closely to East African conditions:—

TABLE IV

MONTH	EVAPORATION	
	Shelterbelt protection	Open steppe
	Inches	*Inches*
April	2·19	3·02
May	4·24	6·05
June	3·48	5·15
July	3·31	4·94
August ..	4·48	5·68
September ..	2·79	4·24
	20·09	29·08

That is to say, evaporation in the open was found to be 44 per cent greater than evaporation in a shelterbelt zone; this figure is rather greater than corresponding figures from America, where, however, the observations were concerned with a single shelterbelt only. They are about the mean of a series of East African observations where, also, only a single shelterbelt was used. It appears that the effect (in reducing evaporation) of a series of belts is greater than that of a single shelterbelt.

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[1] Leontievsky, N. P.—"Rol Drevesnykh Zashchitnykh Polos V Povyshenii Urozhainosti." (The Role of Forest protective belts in raising Agricultural yields.) *Zhurnal Geofiziki*, Vol. 4, No. 1.

The records further indicate a change in the precipitation-evaporation ratio from 46.5 per cent in the open to 76.5 per cent in the protected area (Danilov *ibid.*). A check-up on soil-moisture conditions shows that this is better in protected areas. As far back as 1890, determinations were made at Kherson (Bychikhin *op. cit.*) on an estate planted up with shelterbelts only ten years before. Samples were taken down to 3.3 feet. The average moisture content on the open steppe was 12.12 per cent, and in the protected fields 12.91 per cent to 13.85 per cent, depending on the orientation of the shelterbelts.

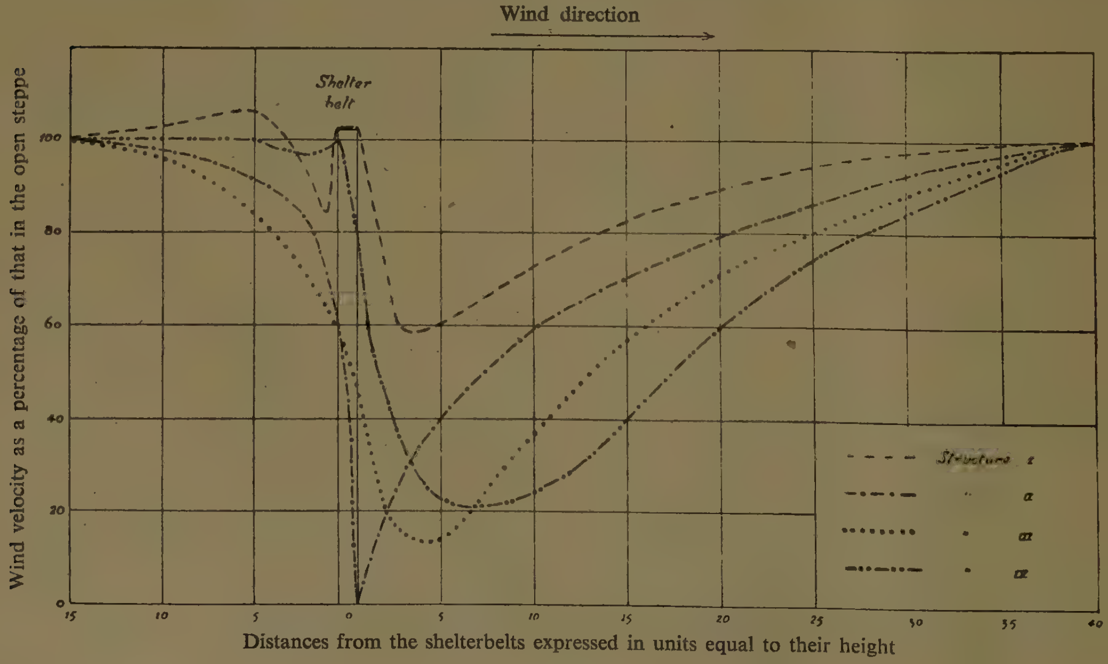
Closely allied to this is an effect of shelterbelt planting not included in the original objects—the increase of relative humidity. At Kamennaya (Leontievsky, *ibid.*) the difference in average relative humidity, comparing the open with the protected areas, for the period April to September during the years 1918 to 1922 varied from 0.5 per cent to 4.5 per cent. The mean humidity during the five years for the protected area was 69.3 per cent, as against 66.7 per cent for the open steppe, a favourable difference of 2.6 per cent. Even more important is the mitigation of extremes of low humidity as shown by favourable differences of from 4 per cent to 8 per cent between average monthly lows for the same two locations over the same period of five years.

Object number (4)—the retention of snow—is not of interest in East Africa; the benefit due to this aspect of shelterbelt planting will not be available in a tropical country.

With regard to object number (5)—raising the water table—such figures as are available tend to show that shelterbelts have no effect. At Kamennaya investigations were carried out to a depth of 13 feet without disclosing any difference between the open steppe and the protected areas at the greater depths.

For object number (6)—decreasing the range of temperature fluctuations—figures show a slight tendency towards equalization in the protected areas; within the shelterbelts, as might be expected, this tendency becomes definite.

Object number (7)—the attraction of rain—is the most controversial. There is a school of thought which admits that if widespread destruction of forests takes place, rainfall will decrease, but denies that rainfall will again increase if the forests are replanted. There is an interesting example of this in Slich's *Manual of Forestry*, Vol. I (which is much more than a



manual of forestry). An increase of rainfall over some years followed, after some years, the replanting of forest in the Central Provinces in India. Every conceivable argument was used (not by the gifted author) to show that the replanted forest could have nothing to do with the increase in rainfall; the final argument was that the rain records were wrong! Slich does not give his own opinion.

The Russian figures have been watched with great attention, particularly in the U.S.A. It would seem to be too much to expect that tree-belts 50 to 100 feet wide and 1,500 feet apart could have the effect of attracting rain, and some American observers think that the question must be left open. Table V gives figures from Kamennaya (Danilov, *ibid.*):—

TABLE V

YEARS	AVERAGE RAINFALL			
	Shelter-belt protection	Open steppe	Increase percentage on protected fields	
	Inches	*Inches*	*Inches*	*Per cent*
1918-24	17·30	15·11	2·19	14·49

In respect of these figures the usual criticisms have been made.

It should be noted that the greatest differences occur in the winter months; it is possible that shelterbelts have a greater influence on snowfall than on rainfall. However, scientific opinion in the U.S.A., in dealing with the criticism that the differences are no greater than might possibly be accounted for by some difference in the exposure of the gauges, states, "If this is not the explanation, the consistently higher figures for the shelterbelt area, year by year, denote a trend of great significance."

Object number (8) is redundant; it follows logically on the attainment of the others.

With regard to object number (9)—the control of soil erosion—so far as wind erosion is concerned, the effects of shelterbelts are of importance. The reduction of surface wind velocities not only checks soil blowing, but seems to lead either to the enrichment of humus content by collecting soil particles blown from the open steppe, or to the prevention of deterioration. Recent investigations at Kamennaya and Mariupol reveal a deepened humus layer in the protected areas. It is not considered possible that this increase in humus content is due to leaf fall from the trees of the shelterbelt over a period of about 50 years. At the former station, in the open, the depth of humus was found to be 24.08 inches; 700 feet to 1,000 feet from the shelterbelt, 26.20 inches; and at 25 to 350 feet from the shelterbelt, 28 inches. The percentage of humus was also determined; this increased from 6.10 per cent in the open to 7.08 per cent at 35 feet from the shelterbelt.[1]

So much for Russia. It would appear that shelterbelts have proved their value over a vast area. Types of construction and species of trees used have not been dealt with. The investigations of Panfilov into wind velocities in relation to shelterbelts have tended to change Russian opinion with regard to types of shelterbelt, and the species of trees used is not of great interest in East Africa.

Now for the Great Plains region of the U.S.A., a region that extends roughly from latitude 31 north to latitude 48 north, and from longitude 90 west to longitude 101 west. The climate is of the continental type, characterized by extreme variations of temperature (from 0° to 108° F.); the precipitation is low and the rate of evaporation high. In the north the precipitation varies from 24 inches to 16 inches, east to west, and in the south from 29 inches to 22 inches, also east to west. Free water evaporation in the warm season is 30 inches in the north and 53 inches in the south. The whole area suffers from desiccating winds in summer, the average velocity being about 12 miles per hour. Typical soils are the "Chernozem" soils, similar to those found in the Ukraine in Russia, and there is a considerable area of "bad lands" where, it is considered, trees cannot be established.

Here there is not yet in existence any great system of Government-planned shelterbelts, but there are considerable areas of private plantings and the catastrophe of 1934 led to a comparison of results obtained in the shelter of these plantings with those in the open prairie. The data obtained covers too short a period of time and too great a diversity of conditions to be taken as a guide. The U.S.A. Forest Service say, "The actual effects of shelterbelts on crop yields are, so far as they have been measured, largely favourable. Further tests and experiments are needed. . . . Most observations in this country have been confined to shelterbelts already established of variable composition, density, and extent, and on fields planted to a single crop in one place and another crop in another place." ("Possibilities of shelterbelt planting in the Plains Region."—Washington, 1935.)

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[1] Tumin, G. M.—"Borba S Zasushlivostiyu Pri Pomoshchi Lesnykh Polos V Kamennoi Stepi." (Struggle against Drought in Kamennaya Steppe by means of Forest Belts.) Voronezh, 1926.

However, the data so far obtained have decided the U.S.A. Government to sponsor a shelterbelt programme in those parts of the Great Plains that are worst affected by wind and drought; this shelterbelt zone is to be 1,150 miles long and 100 miles broad, from east to west. At various times rumours have been heard that the project has been abandoned, but work is still going steadily ahead. The immediate object is the planting of 1,282,000 acres to shelterbelts at a cost of about 32 million dollars (£8,000,000 at present rate of exchange).

It may be of interest to note that a single U.S.A. Government appropriation for relief of distress in the Great Plains in 1934 was 528 million dollars (£132,000,000).

With regard to shelterbelt effects in the U.S.A., American observers have known for some time that shelter reduces evaporation to leeward. F. H. King gives some figures in two of his books, *The Soil* and *Irrigation and Drainage*. The shelter in respect of the observations in Table VI was provided by a grove of black oaks, 15 to 20 feet high, and the evaporation is from a wet surface of 27 square inches.

It will be noted that the evaporation at the three nearer stations was 19 per cent less than at the three outer ones.

TABLE VI

Distance from shelter in feet..	20	40	60	280	300	320
Evaporation in c.c.	11·5	11·6	11·9	14·2	14·5	14·7

A further interesting note is given in respect of a clover field, 780 feet wide; evaporation 300 feet to leeward was 40 per cent greater than at 20 feet. The observer remarks, "In the case of groves, hedgerows and fields of grass, the protection results partly from their tendency to render the air which passes over them more moist, and partly by lessening the surface velocity of the wind."

From such records as are available it would seem that about 200 years ago natural conditions in the Russian Ukraine and the Great Plains were approximately similar. The virgin soil of the Great Plains was probably more fertile, and they also had an initial advantage in the fact that, while the uplands were predominantly grasslands, there were still some millions of acres of forest, chiefly riverine, when the first recorded exploration was made by Lewis and Clark, while the Ukraine was almost treeless. The contrast between the present states of the two areas is therefore the more remarkable.

The deterioration of the Great Plains appears to have passed almost unnoticed and without public comment until 1866, but the work of destroying the fertility of the land went on without ceasing. In the early days large areas of forest were destroyed by natives (Red Indians); to this was added at a later date destruction of forests to supply fuel for the river boats on the Mississippi, Missouri and Red Rivers. To complete the work, in the boom years, 1916-19, marginal lands were ploughed up and sown to wheat and "corn" and largely left unprotected from the wind. Whereas settlers of German and Scandinavian descent maintained and even extended their shelterbelts, others cut them down for fuel and did not trouble to replant; the former are still on their land, the latter largely on public relief. In so far as the Great Plains region is a desert, it is therefore a man-made one.

The extent of the catastrophe of 1934 is difficult to visualize. The Chief of the U.S.A. Forest Service refers to "Great dust storms, nature's own manifestation of land disorders, which arose in the Great Plains region, and blanketed almost the entire eastern half of our country." To transfer the scene to Europe, this would compare with a disaster in which the top soils of Spain, Southern France, and Italy were torn off by hot winds from Africa and carried north, blanketing the countryside as far as Denmark and Scotland.

It is considered that the Great Plains disaster would have been prevented by an efficient system of shelterbelts, and that it will not occur again after the present programme is completed and the belts have grown sufficiently to make their influence felt.

Seventy years before, far-seeing people had tried to get Great Plains agriculture on a sound footing. The Commissioner of Lands in 1866 petitioned Congress to put part of the region under forest. He stated, *inter alia*, "If one-third of the surface of the Great Plains were covered with forest, there is every reason to believe that the climate would be greatly improved, the value of the whole area as a grazing country wonderfully enhanced, and the greater portion of the soil would be susceptible of a high degree of cultivation."

In 1873 the Timber Culture Act was passed. This provided for the grant of a quarter section of freehold land (a section is a square mile) to those planting 25 per cent, i.e. 40 acres, with trees. Much land was taken up in this way, but there was a great deal of fraud, and in many cases there was no attempt to maintain the groves after title was obtained. There was also much wasted effort owing to ignorance and inexperience, the use of unsuitable methods and species. The most common mistake was too wide a spacing of the original plantings; a forest officer would have advised, "Plant close —even 2 feet by 2 feet—and thin out afterwards."

Much further legislation was passed, culminating in the Clarke-McNary Act in 1924. Among other things, this provided expert advice and supplies of planting stock of suitable species having regard to the ecology of the various regions; it also provided for reduction of taxation where approved plantings were established.

So much for the U.S.A. The situation there would appear to be that for the last half century a small number of observant and far-sighted men have been fighting a battle to prevent their fellow men ruining their land and themselves; up to now it cannot be said that they have succeeded, but others have taken up the fight, and the shock troops of the attack are shelterbelts.

Hungary and Ceylon can be dealt with briefly.

In Hungary, to the south-east of Budapest, the plain, the "Pouszta," was formerly almost entirely devoted to stock-raising, and was practically treeless. As might be expected, when crop production was begun, the wind did a great deal of damage; added to the strong, steady wind are great variations in temperature and a low relative humidity; precipitation, taken by itself, is adequate; Budapest averages 24 inches annually.

Round Szeged, about 8,000 acres of shelterbelts have been planted in the last 40 years, and results were so favourable that a law was passed in 1923 making these plantings compulsory; the wishes of the owner of the land were taken into consideration as far as possible and taxation on his land was reduced.

The effect of shelterbelts on fruit crops was not only to increase yields but also to accelerate ripening; in many cases this is desirable, as the early crop fetches the highest price.

Figures from Rétfalu Experimental Station are given in Table VII.[1] The crop in question is strawberries, and the fields are protected by two shelterbelts of *Quercus cerris* L., about 23 feet high.

TABLE VII

HARVEST	Distance from Shelterbelt			Percentage increase 98′ to 20′
	20′	59′	98′	
	Tons per acre	*Tons per acre*	*Tons per acre*	*Per cent*
Annual average	4·062	3·390	2·095	93·89
Average, first 10 days of bearing	0·847	0·402	0·268	216·04

At 98 feet, it is stated, the protective influence of the shelterbelt is still being felt. Figures for crops grown in the open as compared with shelter are not available, but if they were it would almost certainly be found that the difference in favour of shelter was even greater than indicated by the foregoing figures.

In Ceylon it is the practice to leave belts of jungle as windbreaks when clearing for tea planting. Where this has not been done it is the practice to plant shelterbelts, not only for the prevention of evaporation and wind erosion but also for the protection of the tea bushes themselves. Tea, following the general rule, dislikes wind; where the Russians are growing tea in the South Caucasus, they have found that tea bushes growing without shelter suffer "grave mechanical and physiological damage" from the wind (Doledze, "Windbreaks on Tea Plantations"), and that shelter increases the crop by about 200 per cent.

Comparative figures are not available from Ceylon, the reason doubtless being that all tea is grown in shelter. One textbook on tea (*Tea Planting in Ceylon*, Elliot and Whitehead) emphasizes more than once the desirability of shelter, but gives no reasons; the authors probably assume that these will be known to readers.

In East Africa no data have been published in connexion with shelterbelts, so far as is known. This is probably due to the fact that there are only some half dozen artificial shelterbelts in the country, although some natural belts have in some way survived. In the following notes attention will be devoted mainly to the lower altitudes, as it is there that the need for some amelioration is most urgent, but this is not to say that conditions at the higher levels could not be improved.

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[1] Institute Internationale d'Agriculture.—"Protection des Forêts et des Cultures Agricoles contre le Vent." (Protection of forests and field crops against wind.) Rome, 1933.

Although figures relating to shelterbelt effects are lacking, a certain amount of data in connexion with rainfall and evaporation is available. Gillman (Geol. Surv. Dept. Tanganyika Bull. 5, 1933) puts the evaporation from Lake Tanganyika at 1,350 mm. and the precipitation at 900 mm. per annum; the precipitation-evaporation ratio is therefore less than unity—0.66. On a line from Nairobi to Thika—a line passing through a closely settled district—the average annual rainfall approximates to 900 mm. (35 inches), but the evaporation seems to be higher. From observations carried out at Makuyu, extending over five years, average annual evaporation from a free water surface appears to be about 85 inches.[1] Evaporation is highest in March and October (before the rains break) and lowest either in April, August or November; this would make the precipitation-evaporation ratio 0.41, which compares with lows in the Russian Ukraine and the Great Plains of the U.S.A.

At this stage two questions may be put:—

(1) Is moisture a limiting factor in crop production in East Africa generally?

(2) If so, can shelterbelts increase the available moisture, or conserve it until crops can make use of it?

The answer to (1) is undoubtedly in the affirmative. Certain restricted areas in East Africa—the Eastern Usambaras, Bukoba, parts of the Nyumbeni Mountains (north-east of Mount Kenya), and perhaps the Western Mau—have ample precipitation; elsewhere, below 8,000 feet, moisture is a limiting factor for the majority of crops. Further, in some parts of Kenya, e.g. Thika-Ruiru, over 50 per cent of the annual rainfall occurs in two months, November and April; in some parts of Tanganyika the same proportion falls in March and April. Typical annual rainfall figures are given in Table VIII. The conservation of moisture is clearly of some importance.

In respect of the Ithanga figures, if the last seven days of March and October, and the first seven days of May and December are taken into account, the above tendency is much accentuated.

TABLE VIII

(Isolated falls of less than 0·25 of an inch have been excluded as not being effective)

	KENYA—Ithanga			TANGANYIKA—Kingolwira		
	1937	1938	1939	1937	1938	1939
	In.	*In.*	*In.*	*In.*	*In.*	*In.*
January ..	1	3	1	4	1	—
February	—	—	—	2	3	1
March ..	3	3	2	11	8	8
April ..	12	7	14	8	7	5
May ..	8	5	1	2	2	3
June ..	2	—	—	—	2	2
July ..	—	—	—	—	—	—
August ..	—	—	—	—	—	—
September	—	—	—	—	—	—
October ..	5	4	—	3	3	—
November	11	14	7	1	3	—
December	5	6	—	4	—	3
	47	42	25	35	29	22
April plus November	23	21	21			
March plus April ..				19	15	13

The answer to (2) is that in East Africa moisture can be conserved by means of shelterbelts. This is to be expected from experience in other lands, but in the tropics the sun plays a greater part in inducing evaporation than in the temperate zone, and shelterbelts specially constructed to provide shelter from the wind do not give protection from the sun's rays. Observations, however, made in East Africa show that evaporation is greatly reduced by shelterbelts. It appears to be further reduced by providing shelter from both wind and sun, when the shelter provided is a tree, or plantation of trees, but to what extent this reduction in the rate of evaporation is due to the greater humidity of the atmosphere, compared with the open, owing to the transpiration of moisture by the tree, has not been determined. In normal times this would not be a matter of difficulty, and the results would be of interest in dealing with the question of shade for coffee.

The figures that follow have been obtained with apparatus available to all: white china containers for water, giving a wet surface of 27 square inches when holding 500 c.c. of water at 25° C. (77° F.); a measuring glass graded in c.c.; Centigrade thermometers; soil boxes, and a spring balance graded in kilograms and centigrams. The lack of a sensitive and accurate weighing-machine graded in kg. and grams, and weighing up to 30 kg., was felt in dealing with soil boxes, and these results are only approximate. In dealing with evaporation from a free water surface, it was found that nothing was gained by first reducing the water to a temperature of 20° C., and the water was allowed to stand in the open before being filled into the containers.

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[1] The difference between this and the figure given for Lake Tanganyika may be due to two reasons: at Makuyu for seven months of the year there are strong steady easterly winds with a comparatively low relative humidity, conditions not found on Lake Tanganyika; further, evaporation is less in the vicinity of large sheets of water than in the surrounding country.

Modern atmometers have not been used, but differences in evaporation in East Africa are so great under varying conditions that highly sensitive and accurate instruments are not necessary to measure them to 1 or 2 per cent. Atmometers of porous porcelain will be referred to later.

In dealing with evaporation from a free water surface, no matter what type of container is used, as the water level sinks the wet surface gets a certain amount of protection from the wind, provided by the rim of the container; there is therefore a slight tendency towards equalization of figures relating to the open and shelter. Elsewhere attempts have been made to overcome this by adding measured supplements of water at regular intervals, but in the tropics the difference between the temperature of the original and added water may still lead to error.

The figures shown in Table IX were obtained in mid-March at an altitude of 4,700 feet. The temperature at midday was 86° F.; a free water surface of 27 square inches was used. Exposure was from midday to 2 p.m. The figures in c.c. represent the loss by evaporation in the various situations; the percentages represent the decrease of evaporation in the sheltered situations.

TABLE IX

Evaporation				Nature of Shelter
In the open	In shelter			
	Distance from shelter			
	30′	60′	90′	
c.c. 67	c.c. 49 27%	c.c. 49 27%	c.c. 50 25%	Grove of *Eucalyptus citriodora*, rather open 90 ft. high.
67	47 30%	48 28%	51 24%	Grove of *Cupressus lusitanica*, dense, 18 ft high.

At 30 feet to leeward, the grove of *C. lusitanica* either gave better shelter than the *E. citriodora* or added more humidity to the atmosphere—probably both.

Any attempt to correlate evaporation from a free water surface with that from the soil can only be made for a particular soil in one of its many varying conditions; for instance, a light red soil containing 10 per cent of sand and 13 per cent moisture lost 0.60 c.c. per square inch in the open while a free water surface lost 2.49 c.c. per square inch; but as the moisture content of the soil was increased the rate of evaporation rose rapidly.

The relationship, however, between evaporation in the open and in shelter is approximately the same for soil boxes as for a free water surface. Two soil boxes, each of 189 square inches, and each containing similar soil and an equal content of added water, were put out, one in the shelter of a grove of *Cupressus torulosa* and one in the open; the first lost 160 grams and the second 210, a difference of 31 per cent in favour of shelter.

In experimenting with soil boxes it was found that, apart from shelter provided by trees, it was possible to control evaporation in a number of ways to an extent of 18 per cent. It might be worth while pursuing this line of investigation having in mind delicate crops with a potentially high cash yield per acre.

It would therefore seem that shelterbelts would, in East Africa, have at least some of the advantages noted elsewhere; they would reduce wind velocities and wind erosion, and conserve soil moisture. In those maize-growing districts where rainfall can only be relied on for the first fifty days of the growing period, this is desirable. If in addition it is found that ripening of grain is accelerated, it is reasonable to assume that this would lead to larger yields under the same rainfall conditions.

It should not be impossible to obtain definite data bearing on those points. A few miles from Nairobi, on the Machakos road, on the windy Athi Plain, there is a pioneer shelterbelt planting; the prevailing wind is east, and there are four belts in series from east to west, oriented nearly north and south. The main belt to windward is of *Eucalyptus* and the others of wattle. While the choice of species may not be ideal, rapidity of growth was probably a deciding factor in their choice.

It would be interesting if the owner would agree to the planting of, say, a quarter of an acre of maize in shelter, and the same area in the open; to this might usefully be added, in view of alfalfa figures from Kamennaya, a quarter of an acre of lucerne in shelter and in the open.

With regard to coffee, almost anything one can say about this crop, except banalities, is controversial. Apart from the question of the conservation of soil moisture, however, the weight of opinion seems to be that coffee, like tea, dislikes wind. One authority (Macdonald) goes the length of advising planters that when they have the choice of good soil in a situation exposed to the wind and poor soil in a sheltered position, they should choose the latter for planting up coffee. It is difficult to agree with this; the sensible thing to do appears to be to choose the good soil and either leave shelterbelts when clearing or provide them.

Much coffee has been planted in Kenya in situations exposed to the east wind, and no protection provided; on the other hand, in one district the coffee has shelter owing to the fact that shade trees were planted along with the coffee, and the more easterly plantations shelter the others. Trees were also planted which have the effect, whether intended or not, of breaking up the force of the wind. This district (Upper Kiambu) is generally regarded as the most steadily successful coffee-producing district in Kenya, and this in spite of the fact that the species of shade and shelter trees cannot be considered the best available. There are many plantings of various species of *Eucalyptus*, and the shade trees in the coffee are frequently *Grevillea robusta*, both of which are suspect on account of their demands for soil moisture near the surface.

(In the month of October for some years in succession on an Ithanga estate it was observed that coffee bushes within 20 feet of *Grevillea robusta* 14 years old were showing all the signs of acute distress; while those within a like distance of a *Mukuyu*[1] (*Ficus*) tree in an equally exposed situation were in good heart. The *Grevillea robusta* were removed.)

It is not claimed that shelter from the wind is the sole reason why coffee planting is more successful in Kiambu than in any other district; better soil, better rainfall, and more suitable altitude and climate may also be reasons.

Shade for coffee is a form of shelterbelt, if a rather specialized one. Here not only are the moisture demands of the species of shelter tree of importance, but also the soil horizon from which that moisture will be drawn. The researches of Nutman into the process of photosynthesis would seem to provide an additional argument for providing shade for coffee, but many planters fear that shade trees will make such heavy demands on soil moisture that the coffee will not be able to compete. It is possible to get a fairly close approximation to the amount of moisture saved by shelterbelts proper, plus shade trees, but, so far, the unknown factor is the amount of moisture consumed by the shade trees themselves. Figures have been published on the Continent relating to the amount of moisture transpired by beeches about latitude 54° N., but it would be unwise to draw from these conclusions with respect to East African species; the interesting point is that this figure has either been measured or estimated.

For young trees this figure can be got with a little trouble, but for trees of any size a light railway and weighbridge would be necessary. If figures for moisture demands by shade trees can be got, the question of shade for coffee, so far as the availability of moisture is concerned, becomes largely a matter of arithmetic; the advisability of influencing the C/N ratio of the protected crop is another matter.

Table X shows evaporation recorded from a free water surface in the month of October. There was a strong steady east wind; temperature at midday was 85° F.; shelter from wind was provided by a grove of *C. lusitanica*, and partial shelter from wind and sun was provided by a *Mukuyu* giving about 95 per cent shelter from the direct rays of the sun and about 90 per cent shelter from the wind; exposure was from 11 a.m. to 2 p.m.

TABLE X
EVAPORATION

In the open	Shelter from wind	Partial shelter from wind and sun
c.c. 79	c.c. 59 Decrease 25%	c.c. 50 Decrease 37%

Table XI gives the means of three sets of observations with different trees supplying "partial shelter". In these observations exposure was from midday to 2 p.m.

TABLE XI
EVAPORATION

In the open	Shelter from wind	Partial shelter from wind and sun
c.c. 67	c.c. 50 Decrease 25%	c.c. 41 Decrease 39%

On one occasion it was found that evaporation in the open was 84 per cent greater than in the shelter of a *Mumbo* (*Ficus* sp.). This figure has not been included in the table.

An endeavour will be made to get these figures checked by the best instruments available; at present, it is suggested, atmometers of porous porcelain, working in pairs, the one white and the other black. (*See* Burton E. Livingston in *Ecology*, Vol. XVI, No. 3.)

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[1] Indigenous trees will be referred to by their native names; as these vary from district to district, a list of botanical names will be given at the end.

It has been claimed that coffee bushes themselves provide their own shelter, but it has been noticed that where the coffee is planted in straight lines the wind blows down the rows with a velocity equal to, and sometimes exceeding, that in the open; planting on the contour seems to give more protection from the wind. Differences noted between evaporation in the open and in an unprotected coffee field vary from nil (in October, 1933) to 27 per cent. Variations will be found from estate to estate, and from field to field. Suggested factors are the age of the bushes, the extent of the area they shade, whether they have been recently pruned or not, the orientation of the lines, whether planted on the contour or not, and the season.

In considering species for this special purpose (shade for coffee) it would appear that *Muringa* (*Cordia* sp.), an indigenous tree, and *Albizzia moluccana*, an exotic, would both be more suitable than *Grevillea robusta*; they are both fast growing, but kindly. The *Cordia* is of rather a straggling habit until the main stem takes charge. The *Albizzia* has many points in its favour—size, shape, leaf-fall, and nature of shade provided. It is known to "nurse" coffee at altitudes round 5,000 feet, and is one of the Leguminosae. Disadvantages are brittleness (large branches will break in high winds), liability to borer attack, liability to root rot (not noted in Kenya with a rainfall of 37 in.). The brittleness would not be a serious drawback if plantings were regular, and a windbreak of a taller species were provided.

Generally speaking, the East African species of *Ficus* are not suitable for use as shade trees owing to the density of their foliage (although the *Mugumu* (*Ficus hochstetteri*) is satisfactory in this respect) and their low-branching habit, which would make pruning necessary; but the claims of the *Muchosa*, a *Ficus* found on the Ithanga Hills, might be considered. It does not appear to be epiphytic, and is of a more upright habit than its relatives. One of the great advantages of a *Ficus* as a shade tree is that it has a very long taproot, and draws its supplies from a soil horizon so far down that coffee could scarcely be affected by competition for moisture.

Pruning of shade trees, it may be added, is a normal plantation activity in Java. During the six months' dry season the trees are allowed to grow unchecked, but on the Meteorological Department giving warning of the approach of the rains they are heavily pruned (A. Pratt; personal communication).

With regard to sisal, it is possible that in those semi-arid districts where all the effective precipitation takes place in a few weeks, shelterbelts might improve yields. It has been observed that in sisal, where the rows are orientated east to west, the evaporation is greater than in those fields where the rows are north to south; here the sisal itself provides a certain amount of shelter from the east wind. Where trucking arrangements permit, it would seem better to orient the rows north to south rather than east to west.

In any of those districts where 50 per cent of the annual rainfall takes place in two months, and winds are strong, shelterbelts would probably increase yields. It is suggested that this and the orientation of rows are suitable subjects for investigation at the High Level Sisal Research Station at Thika. It is improbable that the shelterbelts would prove so valuable under the more humid conditions found at Mlingano.

With regard to the construction of shelterbelts, this is largely a matter of sound forestry practice, but it is possible to profit by the mistakes of others. In Russia, in the early days of shelterbelt planting, many valuable years were lost by spacing the original plantings too widely, mixing unsuitable species, and importing exotics into conditions under which they would not thrive; so that reliance should be placed mainly on indigenous species, although exotics may be useful for special conditions.

In East Africa the construction of shelterbelts presents few problems compared with other countries. The belt should be oriented north and south, placed to the east of the area to be sheltered, and made as broad (from east to west) as possible. It should have the taller growing species in the middle and the shorter on the outsides. For some years a very dense type of belt was favoured, but now opinion is veering round to a more open type. The reaction of wind to various types of shelterbelt is shown in Fig. 3. The easiest type to construct, that of medium density above and open below, seems to give the best results for all-round purposes.

At altitudes approximating to 5,000 feet in Kenya, for a belt of 20 rows planted up 6 feet by 6 feet on good red soil, the following is suggested: from east to west, first, five rows of *Muringa*, ten rows mixed *Mvule*, *Munyama* and *Musizi* (*Chlorophora excelsa*, *Khaya anthotheca*, and *Maesopsis Eminii*), finishing with five rows of *Ficus*, preferably *Mumbo* and *Mukuyu*, owing to their heavy leaf-fall.

These trees are all indigenous in East Africa. The first four mentioned are valuable as timber (*Ficus* is useless either as timber or fuel) and are strong fast growers at 4,700 feet. *Mvule* particularly is a hardy, widely distributed species, being found under varying conditions in Tanganyika, Kenya and Uganda, and as far west as Nigeria, where it is known as *Iroko*. There is an idea abroad, even among those with some knowledge of forestry, that its "ceiling" is 2,000 feet. This is not the case. In the Western Usambaras it is found at 4,000 feet, which is roughly equivalent to 5,500 feet in Kenya; it has been noted at 5,000 feet on the Nyumbeni Mountains, and it is found in Kyagwe and Busoga at 4,000 feet. Its bulbous taproot makes it drought resistant, but there are two difficulties which may be met with in establishing it. One is the gall worm (*Phytolima alata*), but if all *mvule* in a new district is planted about the same time, it is unlikely that this pest will find out about it in time. The other difficulty is that at some of the higher altitudes the local squirrel has found that the roots are good food, and pulls out young stock at the rate of 10 to 15 per night. This can be got round by fencing the newly planted stumps with sticks or sections of sisal pole 3 feet long. After the stumps have sprouted the squirrels leave them alone.

Munyama (*Khaya anthotheca*) is the mahogany from the Budongo Forest in Uganda, where it is found at altitudes round 4,000 feet. It is a very beautiful tree, probably the most beautiful of all the mahoganies. It appears to have a larger leaf than its relative *mkangazi* (*Khaya nyasica*). Another relative, *Khaya senegalensis*, is well worth a trial (so long as it is regarded as an experiment). It is found as far north as latitude 15 N., and has considerable drought-resisting qualities.

The "ceiling" for these species has not yet been found, and, with the climate of Kenya getting hotter, the "ceiling" is probably getting higher.

When it is desired to plant a shelterbelt for coffee the planter may be up against the difficulty that on the obvious site for the belt the soil is not suited to tree growth. When coffee is planted on gently rolling red soil ridges, it is frequently found that where the red soil merges into the vlei there is murram a foot or so below the surface. Here the planter has the choice of planting either a tree which will put its taproot down through almost anything, or a shallow-rooted tree. *Ficus* comes into the first category, and for the second *Cupressus lusitanica*, *torulosa* and *arizonica* have been used with success. There is one such shelterbelt on Punda Milia Estate, Makuyu; it is planted on a thin cover of grey soil overlying murram, and growth has been good in spite of some unkind treatment.

Pure stands of conifers, however, on a large scale, are not recommended; they do not seem to attract bird life in the way that broad-leaved trees do, and bird life is an excellent insurance against insect pests. In Germany large-scale plantings of conifers in pure stands have suffered severely from the ravages of insect pests.

The forestry motto, "Plant close and thin later," applies to shelterbelt plantings, but extremely close spacing, such as 2 feet by 2 feet, employed elsewhere on account of slow rates of growth, are not necessary for the majority of East African species; 4 feet by 4 feet to 6 feet by 6 feet is sufficiently close original spacing, and will keep down the cost of holing.

It has been found elsewhere that one essential to the survival of shelterbelts is good floor conditions. These consist of a thick litter of leaf mould and shelter from sun and wind within the plantation; these conditions also promote growth.

When planting is done near a sisal estate, wider planting, up to 12 feet by 12 feet, can be adopted and optimum floor conditions obtained at once by covering the ground with 12 inches of rotted sisal waste and covering that with dry boles packed as close as possible. The sisal waste should reach to within 6 inches of the trees and the boles to within 12 inches. This is expensive, even where materials are to hand (lowest cost is Sh. 1/60 per tree), but should last for five years, saving ten to fifteen weedings, and results are very good. The chief benefits are the conservation of soil moisture and the lowering of soil temperatures. This method should not be attempted on black cotton soil.

Where there is a danger of cattle or, worse, goats getting into plantations, either for grazing or shade, thorn hedges should be planted round them. Kei apple (*Aberia caffra*) is suitable, or they should be fenced.

Not much need be added about the higher altitudes, as there is a wide choice of suitable species for altitudes from 6,000 feet to 9,000 feet. The majority of the forest stations—in Kenya, at any rate—lie between these altitudes, and advice, information and help are always available.

At extreme altitudes, say between 9,000 and 11,000 feet, it would be a matter of great interest if a further attempt were made to establish *Sequoia*—both *Gigantea* and *Sempervirens*. The odds, it must be admitted, seem against it. Their habitat in the neighbourhood of Monterey, about latitude 36 N., is in what is now a warm temperate climate, but it is probable that they are a survival from a period when the climate was cooler and moister than it is at present. They have been established in England round latitude 54 N., so that they are resistant to frost; here they are now about 75 years old and 90 feet high. A belt of these when fully grown would make its influence felt for 1,000 yards to leeward.

It is, however, at the lower altitudes that there is the most urgent need for shelterbelts; say, on a line from Nairobi to Kitui in Kenya, and in the Central Provinces of Tanganyika. Here, if the country is to be saved from desert conditions, soil blowing and dust storms must be stopped, while a reduction in the rate of evaporation and a more humid atmosphere would be a help to agriculture.

The natives will plant shelterbelts if they are encouraged to do so, although on the subjects of trees, grazing, cattle and goats, native psychology is beyond most white men. On one private estate a slogan (horrible word!) was started: "No trees, no rain; no rain, no food." The old men said it was true; that since all the trees had been cut down the rain had got less, and the squatters consented to get rid of their goats until trees could be established, and even planted some themselves. Further, some natives came in from the reserve and actually paid cash for planting stock of *Mvule*, *Muringa* and *Munyama*.

At these lower altitudes one thing wants careful consideration: tsetse. No one is going to plant shelterbelts if they are going to bring tsetse into a cattle district previously free from it. This question was studied in the Morogoro district of Tanganyika, an area infested with *Glossina morsitans* (also *G. pallidipes*, *brevipalpis*, *austeni*, and if there are any other varieties they were surely there), which appears to be one of the most widely distributed of the tsetse. A boy wearing a white shirt was taken to the scene of roadmaking operations, where the road ran through thick bush (Plate 1). His shirt was always covered with flies, which were regularly "swatted", and *G. morsitans* was identified on several occasions. The scene was then shifted to a plantation of Burma teak (*Tectona grandis*), 17 years old, well looked after, and providing no cover less than 30 feet from the ground (Plate 2). (In June and July there was heavy cover above that height.) Outside the plantation the boy's shirt was covered with flies of all sorts, but as he moved into the plantation they all disappeared, and in less than a minute none were left. This was repeated on four occasions, and the result was always the same. This would seem to confirm the Belgian view that tsetse will not fly higher than 5 metres from the ground, and if they cannot find the cover they like below that height they will not stay.

At the lower altitudes, therefore, shelterbelts should not be ruled out on account of the risk of tsetse, but an open type of shelterbelt should be employed and kept clean-weeded.

Those wishing to get evaporation data for their own farms can get quite a lot of useful information (as the writer did when starting investigations) from two soup plates and a rain-gauge measuring glass.

Trees: Henley called them "God's Sentinels".

GLOSSARY

Native Names	Botanical Names	English Names
Mkangazi ..	*Khaya nyasica* ..	East African mahogany
Muchosa	Unidentified *ficus* sp.	
Mugumu	*Ficus Hochstetteri*	
Mukuyu (Mkuyu)	*Ficus mallotacarpa*	
Mumbo (Soso on Usambaras?) ..	Unidentified *ficus* sp.	
Munyama (Luganda) ..	*Khaya anthotheca*	Uganda mahogany
Musizi (Luganda)	*Maesopsis Eminii*	
Muhunya (Lunyoro)		
Muringa	*Cordia Holstii* (Abyssinica?)	
Mvule, Muvule ..	*Chlorophora excelsa*	
Nkoba (Luganda)	*Lovoa Brownii* ..	East African walnut.
Mukongoro (Kikuyu)		

Note

While information for the foregoing has been got from a wide variety of sources, it is felt that acknowledgment is due to "Possibilities of Shelterbelt Planting in the Plains Region," issued by the U.S. Forest Service.

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EMPIRE PRODUCTION OF DRUGS

II—CAMPHOR

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Camphor, either synthetic or natural, is another of the drugs listed by the Medical Research Council with a rider to the effect that special efforts should be made to increase production within the Empire. In fact, however, according to the latest figures available (1938) more than four times as much camphor is used for the production of celluloid as for pharmaceutical purposes. Synthetic camphor is on the market, and its price normally governs that of the natural camphor.

The name Camphor was originally applied to Borneo or Malayan Camphor, derived from the tree *Dryobalanops aromatica* Gaertn. In the sixteenth century it included Laurel or Common Camphor, *Cinnamomum Camphora* Nees & Eberm., and the meaning of the word in its most comprehensive sense now includes most of the oxygenated products, both liquid and solid, of volatile oils.

Camphors are volatile oxygenated hydrocarbons, usually possessing a peculiar characteristic odour; they are mostly crystalline, insoluble in water but soluble in alcohol. The more important camphors are divided by King into four groups: Peppermint camphor, menthol; Borneo camphor, borneol; Laurel camphor; and Thyme camphor, thymol. Each has its own chemical formula, that of Laurel Camphor being $C_{10}H_{16}O$. This account is concerned with Laurel or Common Camphor, derived from a tree that is of interest not only to planters but also to those concerned with afforestation.

Cinnamomum, the genus to which Laurel or Common Camphor belongs, contains about 80 species of trees, all natives of Southern and Eastern Asia, some, such as Cinnamon and Cassia, being of economic importance. *Cinnamomum Camphora* Nees & Eberm., the main source of natural camphor, is an evergreen tree up to 100 ft., with a girth of 6 to 8 ft. or more. It has grey, fissured bark; alternate, leathery, long-stalked, strongly 3-nerved, ovate-elliptic, acuminate leaves, 2 to 5 in. long, which are pinkish on the young growths, smooth and shining above, whitish or with a bloom beneath. The flowers are yellow and inconspicuous, in axillary panicles which are shorter than the leaves. The fruit is a dark green, rather dry, globose, one-seeded berry, about 0.3 in. in diameter, black when ripe. Both solid camphor and camphor oil are obtainable by steam distillation of the leaves, twigs, wood and roots.

Common Camphor occurs also as a constituent of the volatile oils of Spike (*Lavandula spica* DC.), Rosemary (*Rosmarinus officinalis* L.), Sage (*Salvia officinalis* L.), Siam Cardamom (*Amomum Cardamomum* L.), American Wormseed (*Chenopodium ambrosioides* L.), and Sassafras (*Sassafras variifolium* (Salisb.) Kuntze.). It is not found in *Ocimum* spp., some of which contain Thyme camphor, or in *Ocotea usambarensis* Engl., the East African Camphor, so called on account of its faintly camphor-scented leaves and wood. This tree yields only small quantities of a volatile oil containing cineol.

Distribution

Cinnamomum Camphora is found wild in Eastern Asia from Cochin China to Shanghai, and in the islands from Hainan to Southern Japan, between latitudes 10° and 34° N. The most extensive camphor forests were those of Formosa, especially in the northern half of the island, where the climate is moist and tropical to sub-tropical. The tree has been introduced more or less successfully into India, Ceylon, Malaya, Java, Australia, East and South Africa, Algeria, Florida, California, Brazil, the West Indies, Mauritius, and Madeira. It has been used for reafforestation, windbreaks, avenue and hedge trees, or as a crop plant.

Climate and Soil

For maximum development the camphor tree requires a deep well-drained fertile sandy loam and a sheltered situation, in a tropical to sub-tropical climate with a high rainfall. At Amani it does well on an orange-brown acid friable lateritized clay-loam on steep mountain slopes between 1,650 and 3,450 feet, with an average annual rainfall of 80 in., usually well distributed through the year. Elsewhere it has been grown from sea-level to over 7,000 feet, but probably thrives best below 5,000 feet, generally where the rainfall is 90 in. or over. In America it has been found to be hardy, surviving temperatures down to 15° F., though such frost may kill tender shoots.

Propagation

Camphor may be raised from seeds, layers, branch-cuttings or root-cuttings, or by transplanting root suckers or by budding or grafting. For plantations, plants are best raised from seed. According to different authorities, seeds vary in weight from 2,100 to 5,600 to the lb. Good seed should be white inside when cut open; if black or brown it is useless. The seed is very oily, and like most oily seeds retains its vitality for only a few months.

The seeds can be sown in well-drained and deeply dug nursery beds where the surface soil has been made into a fine tilth. It is essential to have the soil well drained, as the seeds take from two to six months to germinate. When the beds are ready for sowing the seeds should be soaked in water for twenty-four hours to soften them; the heavy viable seeds will sink to the bottom and the lighter, less viable seeds will float. The heavy seeds should be sown in rows three inches apart each way and covered to a depth of half an inch; the light seeds can be sown broadcast and thicker, as it is probable that only a few of them will germinate. If the seeds are sown in seed pans or well-drained boxes of loam, leaf-mould and sand in equal proportions, better results will be obtained than in seedbeds, as the climatic conditions can be controlled and in addition the seeds can be sown more thickly, i.e. one and a half inches apart. As germination will take anything up to six months, water should be given sparingly but regularly. Not more than 20 per cent can be expected to germinate. When the seedlings are large enough to handle, they should be planted out 6 in. by 8 in. apart in well-prepared nursery beds, where they will remain until ready to be transferred to the plantation.

Layering by tonguing or heeling is fairly successful, but slow. The branch at the lowest point of the bend, i.e. where it will be under the soil, is cut halfway through, below a bud, and then slit upwards for a short distance. Branch cuttings, green and semi-green, have not proved successful, especially those from a high-yielding tree. A high camphor content is apparently not conducive to root production, but under experimental conditions at Edinburgh good results were obtained by previous etiolation of the lower part of the branches by excluding light for fourteen days.

Root cuttings, 2½ in. or more long, provided they have good buds, have been very successful in some countries. The cuttings should be inserted vertically in a good sandy compost with the upper cut surface (that which was nearest the stem of the tree) about half an inch below the surface of the ground. It has been estimated that 75 to 100 good root cuttings could be obtained from a tree eight to ten years old without harming it.

Budding and grafting have proved successful in Russia and Italy. For grafting the whip-and-tongue method and approach graft were used, but the latter cannot be used on a commercial scale. The stocks were *Cinnamomum glanduliferum* Meissn. and a camphor-tree strain of *C. Camphora.* If the camphor is being grown to produce a continuous yield (i.e. as tea is grown) the budding or grafting method of propagation will be a doubtful advantage, because coppice shoots will not only be produced by the scions but by the stocks as well.

Spacing and Cultivation

During, or at the beginning of the rains, plants that have attained a height of at least a foot can be transferred to prepared land in which they will remain permanently. When the young plants are moved the long tap root usually produced by seedlings should be pruned back hard, as well as secondary roots and any long and bushy shoots removed.

The spacing of the plants is a difficult matter to decide, for the following reasons: Camphor intended for distillation is grown like tea, with the object of producing frequent crops of leaves and small twigs, and the plants are trimmed into bush or hedge form. Should the crop prove to be unprofitable, the plantation need not be scrapped, as the bushes can grow into trees. In addition to being a very good fuel, the timber is durable and can be used for cabinet work. If camphor production once more becomes attractive, the trees can be felled and all the aerial parts distilled. The stumps should coppice freely, the produce then being used in the manner for which the plantation was originally formed. At Amani the spacing varies from 7 ft. 6 in. between the rows and 3 ft. between the plants up to 18 ft. between the rows and 17 ft. between the plants. Some of the wider spaced plots have been interplanted with other economic trees, such as Podo, Eucalyptus, Cajeput, and *Cedrela odorata.* This is not an advantage, especially where other oil-yielding trees are concerned, as under a pure stand of camphor the leaf litter can be gathered up and distilled. In India the spacing suggested is 6 ft. by 6 ft. to 8 ft. by 8 ft., in Ceylon 8 ft. by 4 ft. has been used, and in Malaya 10 ft. by 10 ft., whilst in America 6 ft. by 15 ft. has been used to facilitate cultivation. Closer spacing is an advantage in that it will retard weed growth, and will be of additional benefit if distillation becomes unprofitable, because selectional fellings can be made in the plantations from time to time as the stand becomes too closely intergrown. Whatever the spacing, the young trees should be kept free from weeds in the early days of their growth, although it is not essential to keep the intervening ground well cultivated.

Variability in Yield

Unfortunately, not all trees of *Cinnamomum Camphora* do yield solid camphor. In some areas a high proportion of camphor with only a little oil is obtained on distillation. In others much oil and little or even no camphor. This variation in the yield of camphor and oil is well known and some years ago it was discovered that great variation also exists in the nature of the oils produced. Again, at Amani it has been found that a tree producing solid camphor from its leaves may produce oil only from its wood. By some it has been suggested that climate may be responsible for the variation; from tests with camphor under cultivation it is apparent that trees grown under optimum conditions frequently yield less camphor than trees in poorer and more exposed situations. It has also been noted that trees wholly or partly shaded have yielded less than those exposed to full sunlight. It also seems that *Cinnamomum Camphora* comprises a number of races or strains, not botanically distinguishable, but varying in yield of camphor and oil. In any planting scheme it is essential that a strain giving a high yield of camphor be grown, though this yield might be considerably reduced if the environment were too favourable for the growth of the plants.

Yield and Harvesting

At Amani, with laboratory distillation, a tree about 35 years old, between 30 and 40 ft. tall, yielded from its leaves 1.3 to 1.6 per cent camphor, the mature wood gave 0.75 per cent, leaf litter mixed with that of *Cedrela odorata*, 0.43 per cent. These figures are high, except the last. A strain whose yield of camphor does not fall below 1 per cent from the leaves and young growths, 0.5 per cent from the wood, and 0.5 per cent from the leaf litter can be considered high grade.

In Ceylon it has been roughly estimated that 1,210 plants per acre will give annually between 14,000 and 18,000 lb. of young twigs and leaves, yielding about 140 to 180 lb. of camphor per acre per annum. In the Federated Malay States 700 three-year-old plants per acre gave about 60 lb. of camphor from one pruning, or 180 lb. per annum in three prunings. In the U.S.A., bushes 8 ft. high spaced 6 ft. by 15 ft., gave 8,000 lb. of trimmings per acre for each of two cuttings, a total of 17,920 lb. per acre per annum, and yielding 175 to 200 lb. of marketable camphor. In the U.S.S.R., 170 lb. of camphor per acre was obtained from two cuttings.

Under favourable conditions the first harvest of leaves and twigs can be obtained two years after planting, i.e. three years from seed. The number of clippings per annum will depend upon the rate of growth; in cool climates, one or two, in hotter and wetter, four or perhaps five.

Distillation Plant

This consists of a boiler for producing steam, a still to take the leaves, twigs, or, if the tree is mature, the chips from the trunk, and a box condenser, containing baffle plates, which rests in a water-bath with a plentiful supply of cold water flowing over the condenser top. Steam is passed from the boiler through the still, where the camphor and oil are removed from the material and passed into the condenser. There the camphor is deposited as crystals, and also settles on the water surface, where at the same time a film of oil forms. The size of the still will depend upon the capacity of the boiler. This should be capable of evaporating from 40 to 50 gallons of water per hour for a still with a capacity of about 150 to 200 cubic feet, to hold a charge of about a ton of leaves and twigs, which is considered to be the most economic. American investigators consider that 200 acres, others 100, is the minimum planted area which normally would warrant the erection of a distillery and refining plant, and that a 500-acre block would probably ensure the minimum cost of production of marketable camphor.

The rate of distillation depends upon a number of factors, and it can vary between three and six hours. When the distillation is completed, the condenser is removed, the crude camphor adhering to the walls of the various compartments scraped out, and the oil collected from the water bath. The waste product in the still is also removed, and, if chips, can be used for firing the boiler.

The crude camphor will contain a certain amount of oil, water and other impurities, but the water and oil can be removed by treatment in a press or with a centrifuge giving a centrifugal force of 550 to 600 gravities. The solid product will still not be pure, and has to go through a process of sublimation with charcoal or lime, when the camphor can be obtained either in transparent slabs or in "flowers of camphor", as desired. The brownish oil is one of the most complex of volatile oils, but its chief constituent is camphor in solution. By fractional distillation and subsequent freezing of the camphor-containing fractions, this camphor can be separated out.

Uses

Camphor was at one time used in the manufacture of smokeless gunpowder and explosives. In 1938 about 80 per cent of the world's camphor was used in celluloid manufacture and the remainder chiefly for pharmaceutical purposes. Medicinally, camphor is, according to Potter's *Cyclopædia of Botanical Drugs and Preparations,* a sedative, anodyne, antispasmodic, diaphoretic, and anthelmintic. Internally it is used in colds, chills, and in diarrhoea resulting from colds. In all inflammatory affections, fevers and hysterical complaints it is of great value. It is beneficial in gout, rheumatic pains and neuralgia. Externally it can be applied in all cases of inflammations, bruises, sprains, etc. Rectified camphor oil is employed as a rubefacient and a mild counter-irritant to rheumatic and inflamed joints.

British Pharmaceutical Standard

A.—Camphor: Melting point, 174° to 177°. Residue on volatilization, not more than 0.05 per cent. It must comply also with a limit test for water.

B.—Rectified Camphor Oil: Not less than 35 per cent of cineol. Specific gravity, 0.875 to 0.900. Optical rotation, +9° to +24°. Refractive index at 20°, 1.465 to 1.470.

Market Quotations

The price of natural camphor is controlled by that of the synthetic product, which was first put on the market about 1907. Synthetic camphor and natural camphor differ only in their action on polarized light, the former being either inactive or only slightly active. The synthetic commercial product is derived from pinene, a substance occurring naturally in turpentine oil, the distilled pinene being saturated with dry hydrogen chloride, and by a series of complicated chemical changes synthetic camphor is the result. Those countries with cheap sources of turpentine, such as the U.S.A., Germany and France, do not need to import natural camphor, and in fact Germany has not imported any since 1920. In Formosa, one of the chief sources of supply of natural camphor, it is possible to manufacture camphor at an export price of sixpence per lb., and that is normally the limit to the cost of its production elsewhere.

At the time of writing, the price has not varied between 14th December, 1940, and 1st February, 1941, according to the *Chemist and Druggist*. Synthetic and Japanese camphor was then quoted at 5s. 2d. to 5s. 6d. a lb.; English refined camphor, 6s. 3d. to 6s. 11d. a lb. in bulk. Chinese camphor oil in drums was fetching 350/- a cwt.

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SOME LESSONS FROM A TOUR OF THE TEA DISTRICTS OF INDIA

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Tea is cultivated under a wide range of conditions in India; at altitudes ranging from near sea-level in Assam to near 8,000 feet in the Nilgiris; under climates ranging from the extremes of heat and of cold in North India to the more equable conditions of South India; on soils ranging from the alluvial plains of Assam to the steep mountain slopes of Darjeeling. In each district a technique of tea cultivation and manufacture has been evolved to suit the local conditions, and the practices of one locality may be contrary to those of another; for example, in Darjeeling the fermented leaf is fired at very high temperatures in order to produce the desired quality, while the high-altitude teas of South India and Ceylon are fired at very low temperatures for the same reason. When planters have been transferred from one district to another and have endeavoured to follow blindly the practices to which they were accustomed, the attempt has often resulted in failure. Similarly, in Uganda, it would be a mistake to copy exactly the methods utilized in any other tea-growing countries, and we must preserve an open mind on controversial matters until we have learnt by experience which methods are best suited to our conditions.

There are, however, certain broad principles common to many tea-growing districts, and some of them will be discussed under the following four headings:—

1. Seed Selection.
2. Soil Cultivation and Conservation.
3. Shade.
4. Estate Planning.

Seed Selection

There are two main groups of tea in cultivation: firstly, the China type, and secondly, the Assam type. They are easily crossed, and, according to modern botanical usage, are regarded as varieties of a single species, *Camellia sinensis* (Linn.) Kuntze. The China type forms slow-growing bushes with small leaves; it has the advantage of being more resistant to cold than is Assam tea, but it gives much smaller yields than the latter under Uganda conditions. In the Botanic Gardens, Entebbe, two bushes of China hybrid tea, planted in 1900, are much smaller than plants of Assam tea planted in 1934.

The Assam tea group may be subdivided into light-leaved and dark-leaved types. Sometimes the term "Assam" is restricted to the former and the latter are known as "Manipuri". Under equable conditions, the light-leaved types usually give the higher yields and the better quality of tea, but the dark-leaved types are more resistant to drought. There are not yet available exact comparisons of the yields of these two types in Uganda, but experience has shown that under sheltered conditions the light-leaved bushes give heavy yields, while the dark-leaved Manipuri teas will grow well under exposed conditions; for example, the plot of Kalline tea at Buwunga, near Masaka, which has grown quite well on very poor soil. Under natural conditions tea is almost entirely cross-pollinated, for it is self-fertile only to a slight degree, and in consequence there is great variation between the bushes of any batch of tea grown from seed; but in the best "jats" or commercial varieties of tea this variability has been much reduced by continued selection of the mother trees, and remarkably even stands are obtained. The plucking surface of some of the best blocks of tea in Assam is as smooth as a lawn, but however good the jat there are yet marked differences between individual bushes—differences in yields, in habit, in leaf size and shape, and in the quality of the tea made from them. The differences in quality are most interesting, and may be correlated with the vegetative characters of the bushes, although the problems are complex. It has been found at Tocklai that bushes of Assam tea whose young leaves are reddish give poor quality, but the reverse seems to be the case in China tea at Darjeeling. Evenness in growth, in flushing and in quality are highly desirable on tea estates, for it greatly facilitates the work of plucking and of manufacture, and it would be a great advantage if blocks of tea could be planted up with clonal material; that is, with bushes which have been vegetatively propagated from a single plant. Experiments in the rooting of tea cuttings at Tocklai are giving such promising results that in time it should be feasible to plant tea clones on a large scale, although, as a rule, the cuttings of bushes of "high" jat are much more difficult to strike than those of "low" jat.

For many years, however, the bulk of tea that is planted will have to be raised from seed, and it is of vital importance that the best available type of seed should be used. The cost of planting tea is so great and the productive life of a bush is so long that it is a great mistake not to sow the best seed that can be procured, even if the purchase does entail an extra initial expense. On some estates in North India, blocks of quite good tea are being dug out and replaced with bushes of a better type. If this practice of replanting has been proved to be economic, surely it is essential that only good tea should be used for new plantings.

The use of seed from bushes that are being plucked should be avoided at all costs. A bush which is flushing vigorously will produce little seed, yet one whose vegetative growth has slowed down will flower and fruit profusely. The use of seed from a plucked garden therefore merely serves to increase the proportion of unproductive bushes. It has been found that there is a marked correlation between the growth of a tea plant in the nursery bed and its yields as a mature bush, and therefore it is advisable to raise a large surplus of seedlings in order that there may be vigorous selection before planting. One of the advantages of "stump" planting lies in the fact that if the seedlings are allowed to remain in the nursery beds for one and a half or two years, individual differences are more easily distinguished than in the case of young seedlings.

If nursery selection has not been practised it will be found that, when the bushes are four or five years old, a proportion of them will be producing little crop of leaf but may be flowering and fruiting profusely. It is advisable that these bushes should be removed as soon as possible and others of a better type planted in their places, for the older a bush becomes the more it tends to devote its energies to flowering and fruiting at the expense of vegetative growth. It should be remembered that it is much more easy to establish infills among young tea plants than among mature bushes with fully developed root systems.

Fortunately, the Dahootea Assam jat imported in 1909, from which the bulk of Uganda tea is descended, was of quite a good type, but continued selection must be carried out if it is not to deteriorate, for, as pointed out above, the bushes which are the most prolific seed bearers usually are those which produce the smallest amount of leaf. The Kalline Manipuri tea at Buwunga also is a good average of its class. As mentioned above, it seems that the light-leaved Assam types will give as good or better yields and better quality in most tea districts of Uganda than will the dark-leaved types. The best Assam jats are less prone to seed production than are other types of tea. This is a factor of especial importance under our long pruning cycles, for it will influence yields of leaf in a manner which is not possible under the annual pruning system of North India. Manipuri tea would be valuable in places where the ground is shallow or stony, but as there is usually a surplus of land on tea estates it is advisable to avoid such spots and to confine the tea to the better areas.

Whatever type of tea is desired, it is essential that the best available seed should be planted. In the case of estates which can afford to import the best seed from India, it is well worth their while to do so. Some of the better seed gardens in Uganda—for example, the one at Kakumiro, near Mubende—compare favourably with the average in other countries, but on many estates much more drastic selection of mother trees is required. On estates which already possess seed gardens, new plots of seed bearers should be established, for it is probable that the production of good seed will fall off when the existing trees are more than twenty or thirty years old. Attention must be paid to supplies of seed for the future as well as to those for the present, for even when the total acreage has been planted, plants for infilling will be needed.

Soil Conservation and Cultivation

On some estates in North India there may be seen a great deal of grass growing among the tea bushes which nevertheless continue to flush well. Although the grass does not depress the yields of tea nearly so much as it would in Uganda, yet, where the ground is level, it seems to be of no value except to shield any soil exposed between the tea bushes. On the steep slopes of Darjeeling the thick covering of grass—it forms almost a turf—is indispensable to hold up the soil, for no cover crop has been found to take its place.

Tea grows so rapidly during the summer months in Assam that most of the labour force is required for plucking and little attention can be devoted to cultivation, so that by the end of the season there is a mass of grasses and other weeds in the tea. Formerly, it was the custom to dig through the tea during the winter months, in order to bury all this weed growth, and it was considered that this digging should go down as deeply as possible, sometimes as much as eighteen inches; but now the deep digging is not considered to be beneficial, and, in fact, there is much evidence to show that it is positively harmful to the tea.

It is difficult to understand why the fetish of deep digging arose at all, because in the process the tea suffers much root pruning. This practice may be of great value in the case of temperate fruit trees, in order to check their growth and to induce them to flower and fruit, but this is exactly the reverse of what is needed on a tea estate. Many estates continue to give an annual digging to their tea, though less deeply than before, yet on some of the best estates in Assam cultivation has been reduced to a minimum; for observation and experiment in both India and Ceylon have shown that intensive cultivation may depress tea yields [2].

If the ground is deeply dug, a fine tilth results, which is most favourable to the growth of succulent weeds and grasses; but if weeding is done by hand, and hoeing is confined to those weeds with perennial root systems, the ground becomes harder and weed growth is repressed. The initial cost of such treatment may be high, but subsequently much less expense is entailed than on repeated cultivations. It may be considered that the lack of cultivation will have a bad influence on the growth of the tea bushes, although there is no evidence that such is the case, providing that the ground is kept free from weeds. Little is known about the habit of truly wild tea or about the conditions under which it grows, but it appears that tea, like coffee, is a forest plant, and that, as in the case of many tropical forest plants, under natural conditions the bulk of the feeding roots would be close to the surface of the soil. It is an established fact that mature coffee will flourish in Uganda on soil which is free from weeds but which has not been cultivated for many years, and the same appears to be true of tea.

Furthermore, it may be felt that the soil of tea estates benefits from cultivation. It is true that the tilth of most soils in temperate regions is improved by cultivation, but there is much evidence that the reverse may be true in the tropics. In the case of some arable crops in India worse results may be obtained by turning over the soil to a considerable depth with an iron plough than will result if the top few inches are stirred with the indigenous wooden plough. It is often stated that cultivation is necessary to produce proper aeration of the soil, but this consideration does not apply to tea estates. Tea will not grow on waterlogged soils (with the exception of the peaty "bheel" lands of the Surma Valley, where the tea bushes form a plate of roots near the surface, above the water-table), and if water can pass through the soil there is no doubt that air can do so as well. One other argument in favour of cultivation may be brought forward: that it increases the rate of percolation of water into the soil. And this argument may apply to very sloping tea gardens, but not to most of the estates in Uganda, for little tea has been planted in this country on steep slopes, and we do not have to contend with storms so excessive as those of other tea-growing countries. (Incidentally, it may be noted that tea often seems to yield better on the sides of valleys than on the flat tops of hills in Uganda.)

There is no doubt that percolation of water into the soil on slopes is best secured by an adequate system of contour ditches and bunds. On one estate in Sylhet most excellent results had been obtained with contour ditches only a foot wide but as much as three feet deep, which hold up heavy falls of rain. Fortunately, there is no need for such big drains in Uganda. If contour drains one foot wide and one foot deep, with the soil thrown in a bund above the drain, are made at vertical intervals of two or three feet, as in Nyasaland, any appreciable loss of water or of soil should be avoided [3]. If such a system of ditches is provided, and the ground between is not cultivated, the minimum loss of water (a most important factor in regions of low rainfall) and of soil should result; for, whereas in disturbed soil the tilth is destroyed and erosion is increased, if the soil between the tea bushes is not disturbed, the fine feeding roots near the surface are of great value in holding it in place. It is improbable that tea will be planted in Uganda on slopes so steep as those of Darjeeling and of Ceylon, where actual terracing is needed to hold up soil and water, but if terraces must be made it is usually better to have a few large ones rather than many small ones, and care must be taken that the soil is not covered in the process. A start should be made at the bottom of the slope, each terrace should be cut out of subsoil and covered with soil from the site of the terrace above. If sloping land is to be planted with tea it is advisable to follow the Nyasaland custom and to make the drains and bunds before the land is staked out for tea, for it is far cheaper to dig drains in bare ground than to do so between the bushes. This consideration applies even more strongly when actual terraces are to be constructed. In Darjeeling much of the tea originally was planted in rows up and down the slope and enormous expense has been entailed in building up the systems of terraces now common there. Just as it is more expensive to make bunds or terraces among planted tea than in bare ground, so also it is much more costly to clean the land after planting. When couch grass (*Digitaria scalarum*) is present, it should all be removed before the tea is put out, or large sums will be needed to eradicate it from among established bushes.

Mention has been made of the fact that no satisfactory cover crop has been found to cover the soil between tea bushes in Darjeeling; nor have good cover crops been found for tea at lower altitudes. Many have been tried but some, such as species of *Desmodium*, are difficult to grow, while others, such as *Indigofera endecaphylla*, tend to scramble up the bushes. Bushy plants, such as *Tephrosia candida*, are utilized to cover the ground in places where the tea will not grow; for example, the sites of old anthills where the soils are rich in lime; but no planted cover has been found so suitable between tea bushes as a growth of succulent weeds, providing that pernicious grasses are excluded. Such a growth protects the soil from the heat of the sun and from being washed away by the run-off of water. In Ceylon, where the tea has been clean weeded, so much damage has been done to the soil and so much of it has been lost that it is difficult to replant areas which have long been under tea, but in India, where the tea estates have had more weed growth, the fertility has been maintained sufficiently to make replanting comparatively easy. On one estate, where very successful replanting was in progress, the land was cleared of the old tea and a crop of *Tephrosia candida* grown for two years before the new tea was put out. *Tephrosia candida* grows poorly in Uganda tea districts, but *T. Vogelli* or pigeon pea might be used here, or, better still, the land might be planted with elephant grass (*Pennisetum purpureum*), a crop which in this country appears to be more valuable than any other in restoring the structure of the soil and in adding organic matter. For some reason, perhaps on account of its effect on the physical structure and water-holding capacity of the soil, organic matter is of more importance in stimulating the growth of tea seedlings than are inorganic manures, to which the seedlings often show little response. When supplies of farmyard manure or compost are available, it is better that they should be mixed with the soil used for filling the holes when tea is planted (up to forty pounds may be used in a large hole) rather than that they should be distributed over areas of mature tea.

If cover crops or weeds are grown among tea bushes there is bound to be competition between the plants for supplies of nutrients and of water. In North India, during the summer months, when the bulk of the crop is picked, there are ample supplies of water both for the tea and the weeds, but under Uganda conditions, where water supply is often a limiting factor to tea production, the same amount of weed growth would greatly depress the yields of tea. The ground, however, must be fully shaded if fertility is to be maintained, and there is no doubt that this end will be best achieved if the complete cover can be provided by the tea bushes themselves. The bushes must be spaced in such a manner that they touch their neighbours; in theory, if each bush is supposed to be circular in outline, a better cover will be secured if the planting is on the triangular system than if it is on the square; in practice, although no bush is a perfect circle, yet the triangular planting does appear to be advantageous in this respect. Distances between bushes should not be too great for them to meet before they are five years old, for the exposure of ground not only causes its deterioration but also increases the cost of cultivation. If the bushes are closely planted at first and if all the vacancies are infilled, a complete cover over the ground will be sooner achieved and heavier early crops may be picked than from widely spaced bushes.

It must be remembered that not only is there competition between the tea and other plants for supplies of soil water but there is also competition between the tea bushes themselves. This is a most important point in Uganda tea areas, where rainfall is much less than in any important tea district of India and where, as mentioned above, water supplies are often the limiting factor to tea production. If the spacing is at five feet, each tea bush will be able to draw its water supplies from an area 50 per cent greater than that of a spacing at four feet and 100 per cent greater than that of a spacing at three and a half feet. Some planters in Nyasaland consider that closely planted tea may be more affected by drought than widely planted bushes, and there are indications that the same may be true in Uganda. Experience and experiment will show what will be the optimum spacings on Uganda estates, but, to judge from the appearance of some of the oldest tea, it will be possible to plant at spacings up to four and a half feet square and five feet triangular and yet to secure quickly, and maintain permanently, a complete cover of tea.

Pruning also plays a very important part in securing a good ground cover. From the start an attempt should be made to produce large spreading bushes. In Assam, where the tea is pruned annually, the "champagne cup" type of bush, with a single short main stem for a few inches above ground level, is common. Under Uganda conditions, where pruning cycles of three or four years are required, it is essential that the bushes should branch as low as possible or the plucking level will become too high before the end of the cycle. It is a great mistake to attempt to obtain heavy yields by hard plucking of young tea. It is far better to sacrifice a little of the early crops in order that the future vigour of the tea may be assured, while it must be remembered that some of the extra returns obtained by stripping all available leaf off the bushes are counteracted by the increased costs of cultivation necessary to control weed growth until the tea has formed a shade over the ground.

During the last few years "slope pruning" has been practised extensively in South India. Where the tea has been growing on hillsides, the bushes have been pruned in order that the tops may be parallel with the slope of the ground and not horizontal, as is usual. "Slope pruning" for the first few years gives an excellent cover over the ground, eliminating the spaces to be seen between flat-topped bushes on hillsides, and the effect is most attractive—a continuous sheet of tea up the hills. The value of the method has not been proved, however, and some estates have reverted to flat pruning, as it appeared that all the vigour of the bushes was being deflected into a few branches growing upwards and that the branches on the lower sides were dying back.

It must not be forgotten that tea bushes, which grow rapidly at first and soon form big frames, may not be able to support these frames if the soil fertility falls too low; if the supplies of plant nutrients become too small, the bushes may die back badly. Every attempt therefore should be made to maintain the fertility of the soil or to increase it. Whenever cotton seed is obtainable at low prices it is well worth while to apply it to the tea, especially to areas where there is a poor stand or stunted growth, for there seems to be no risk that heavy production of leaf from tea in any season increases the risk of subsequent dieback, as in the case of a heavy crop of fruit from coffee. It is far better to maintain or to increase the initial fertility of land on which tea is planted from the beginning, rather than to defer the programme of manuring until both the tea and the soil have commenced to deteriorate.

Shade

One method of diminishing soil exposure and erosion is by the use of overhead shade, and there is a distinct prejudice in favour of planting shade trees in all the main tea districts of India. In Assam spreading leguminous trees are utilized, and of these *Albizzia stipulata* (syn. *A. marginata, A. chinensis*) is the most common, for it is easily established, it grows rapidly, and forms a high spreading crown of light foliage; but it suffers from the drawback that it is often attacked by canker, and trees seldom last in good condition for as much as fifteen years. *Albizzia procera* is also widely planted. It is more erect in growth than *A. stipulata* and, as it is less attacked by canker, it tends to be a longer lived tree. *Albizzia odoratissima* is a smaller, more slow growing species, which is popular with some planters. *Albizzia lebbek* is more open in habit in Assam than in Uganda, but its shade seems to be rather too dense for tea, although its general effect on the bushes is good. *Albizzia moluccana* is not popular. It makes rapid erect growth, but the trees are liable to root rot and are apt to be blown down by wind.

Derris robusta is a large native tree, frequently planted in tea, but it is not generally regarded with so much favour as the species of *Albizzia*. The tree is almost too vigorous in growth, and may compete with the bushes beneath, while it is often defoliated by a caterpillar (*Baradesa emissa*), which does not attack other shade trees. *Dalbergia assamica* is another native tree which is planted among tea. It is especially useful on land which is too poor for *Albizzia stipulata*.

The species of shade trees which are most used in Ceylon tea gardens—*Grevillea robusta* and *Erythrina indica* (Dadap)—are now seldom planted on tea gardens in Assam. The Dadap is especially liable to root diseases, and the planters prefer to grow leguminous trees, such as the species of *Albizzia*, rather than a non-leguminous tree such as *Grevillea*; yet *Grevillea robusta* grows well in Assam, and good old specimens can be seen.

Plate 1

A view in the Darjeeling district, showing a terraced tea garden with scattered trees of *Albizzia stipulata*.

Plate 2

A plot of tea in the Dooars, planted with *Albizzia procera* as a shade tree.

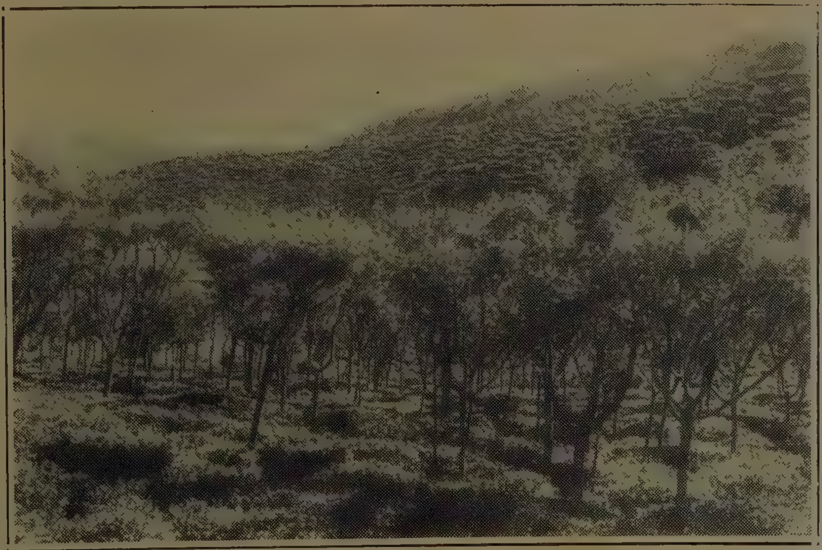

Plate 3

Tea at an altitude of 7,000 feet in the Nilgiris, planted with *Acacia decurrens* as a shade tree.

PLATE 4

Tea at an altitude of 3,500 feet in the Nilgiris, planted with *Grevillea robusta* as a shade tree.

PLATE 5

A block of tea in Assam, showing the shade of *Albizzia stipulata* and the level plucking surface of the tea.

PLATE 6

The surface of a block of high jat tea in Assam, showing the uniformity of the bushes.

In the Dooars, the tea district on the foothills of the Himalayas in North Bengal, many of the shade trees in tea were cut out some years ago, but now they are being replaced. *Albizzia stipulata* and *A. procera* are the species generally planted. The reversion of opinion in favour of shade in the Dooars is due to the fact that it controls Red Spider, which is a great pest in that district. Mosquito bug (*Helopeltis*) also does much damage to tea there, and while there is no proof that the incidence of the pest is less under shade—sometimes it seems to be worse than in the open—yet it appears that shade does definitely assist the tea bushes to recover from the attacks of the pest.

In the Darjeeling district, where the tea is grown at higher elevations, usually between 2,000 feet and 6,000 feet above sea-level, and where many of the bushes are of a China or China hybrid type, shade trees are not so abundant as at lower altitudes and large areas of unshaded tea may be seen, for in many estates the shade trees have been removed. In this district also there is now a tendency to re-plant shade trees and *Albizzia stipulata* is the species most generally used. *Indigofera dosua*, a small local tree, is sometimes employed; it is quick growing, but is liable to root diseases.

In South India most of the tea is planted with shade, and *Grevillea robusta* has been the tree most commonly utilized, but sometimes it suffers badly from leaf fall disease, and therefore other species are being tried. *Albizzia moluccana* is extensively planted, while on some estates other trees, such as *Dalbergia assamica* and *Derris robusta*, are used. Often the shade trees are interplanted with other smaller trees which are lopped to supply a bulk of green material; the Dadap, *Erythrina indica* and *Gliricidia sepium* (syn. *G. maculata*) are utilized for this purpose. The Dadap is sometimes allowed to grow into a shade tree. Tea is planted at greater altitudes—up to 8,000 feet—in the Nilgiris, the highlands in South India, than in the Darjeeling district (which is much farther from the equator and where there is little tea above 6,000 feet), and many estates above 6,500 feet are shaded with wattle (*Acacia decurrens*). This species of *Acacia* has so strong a root system and is so hungry a tree (there is seldom any undergrowth in a wattle plantation) that it is very surprising to see it employed as a shade tree in tea, but no other species has yet been found to replace it at high altitudes, where it is most useful in protecting the tea from frost. *Acacia decurrens* forms a mass of fine roots near the surface, and the bulk of the tea roots are in the soil below. Quite good yields are obtained, for during the monsoons there is an excess of rain and the problem of competition for water supplies is not so acute as it would be under Uganda conditions.

The natural home of tea appears to be in the undergrowth of forests, and therefore it is not surprising that the consensus of opinion among a large body of planters should be that the plant grows better when some shade is provided. It may be that, as in the case of coffee, the leaves of the tea bush cannot assimilate so well in full sunshine as in slight shade. Undoubtedly, shade trees are of value in preventing hot dry winds from impinging on the tea bush. Many tea districts of South India suffer from such winds, and so does the Surma Valley in Assam; yet in the Brahmaputra Valley, where very heavily shaded tea was seen, the action of wind does not seem to be important.

It has been proved at the Tocklai Experimental Station that, when no manures are applied, shaded tea will give larger yields than unshaded tea, and the difference between the crops has been attributed to the fixation of nitrogen by the shade trees. Yet, when nitrogenous manures are applied, there is less response with shaded tea than with unshaded tea. Probably the shade trees take up some of the added nitrogen from the soil [1]. It seems that, if fairly heavy dressings of manures are given each year, there is no actual necessity for planting shade trees in the Brahmaputra Valley (as mentioned above, the shelter effect of trees is not required there). So long as prices are high and it is economic to apply manures, shade is not needed; but if there were a slump, and the money spent on manuring and cultivation had to be drastically reduced, there is no doubt that shaded tea would be less affected than unshaded, for the trees greatly depress weed growth. Shade trees therefore may be regarded as an insurance, assisting the stability of the tea industry. An analogy may be quoted in the longevity of Arabica coffee in South India, where it has been treated as a forest crop, as compared to the short life in other countries, where it has been grown without shade.

One of the problems of the evergreen controversy about shade for tea and coffee is that some people will not effect a compromise. When shade is needed, the trees are planted too closely, and when shade is too heavy the trees are removed altogether instead of pruning or thinning them. Some very good tea was seen under dense shade, but general opinion in Assam is that the shade trees should not be too close. It has been found that the quality of the tea does not suffer if it is grown under *Albizzia stipulata* trees planted fifty feet apart and pruned to give a high canopy of shade. If this amount of shade does not affect the quality of tea in Assam, it is unlikely that it will do so in East African tea districts, which are not subject to such hot moist weather as in the summer in North India and which in consequence do not experience the same rush of crop.

It is interesting to note that in North India there is a preference for spreading, diffuse shade trees, while in South India and Ceylon taller, more erect trees, such as *Grevillea*, are in favour. One explanation of this difference may be seen in the value of tall trees as windbreaks, for hot winds are a much greater problem in South India than in the north, with the exception of parts of the Surma Valley. Tea growing in Assam near sea-level experiences much higher summer temperatures than occur in the tea districts of South India, Ceylon or East Africa, and it is quite probable that the direct shade effect is more important than in places which are never so hot.

Another difference between the use of shade trees in North and South India lies in the value attached in the north to leguminous trees for the fixation of nitrogen. It has been found in Assam that while there is no evidence that short-term leguminous crops are of any value to fix atmosphere nitrogen, yet is seems that trees and also shrubby crops, such as *Tephrosia* and pigeon pea, do actually add nitrogen to the soil. In South India leguminous trees are planted, but little importance is attached to their root nodules, while in Ceylon it has been shown that leguminous crops do not increase the nitrogen content of the soil, although they may be of value in preventing the loss of nitrogen already present. In Africa, too, there is a mass of evidence that the value of leguminous crops lies in the manner in which they protect the soil and absorb plant nutrients which otherwise would be leached out, rather than in the fixation of nitrogen; for it must be remembered that the presence of nodules on the roots of a leguminous plant is not a proof of nitrogen-fixation; many of the organisms which occur in the nodules have not this faculty.

There are two possible explanations of the disparity between the value of nitrogenous plants in North India and in countries nearer the equator. Firstly, it may be due to the difference between the "tropical" climate of the former, which is characterized by a very hot summer and a cool winter, and typical "equatorial" climate, in which there is little fluctuation of temperature with the season. Very little is known about the biology of tropical soil organisms, but there is no doubt that they must be greatly affected by temperatures and that differences in their growth and multiplication would be reflected in the nitrogen status of the soil. Secondly, the fact that the soils of Assam often are richer in lime than those of tea-growing districts near the equator may have a bearing on nitrogen fixation by root nodule organisms, for it has been found that this process is inhibited on acid soils in temperate countries, and it has been found that some leguminous shade trees respond markedly to manuring with lime.

Tea will grow and yield well for some years in Uganda without shade, but while our tea industry is so young it would be a mistake to disregard the experience of other countries and to assume that a certain amount of shade and shelter will not be beneficial to our bushes. Reliable information can be found only by observation and experiment on our estates as to what will be the best trees to plant and what will be the best spacings. As the soils and climates of Uganda resemble those of Ceylon and South India more than those of North India, it is probable that *Grevillea robusta* will prove to be a suitable tree for tea estates in this country; the erect habit renders it most efficient as a windbreak—a very important factor in some of our tea areas. Some of the oldest tea in Uganda is growing and yielding well under the shelter of this species. *Albizzia stipulata* also grows well in Uganda, and does not suffer so much from canker here as in Assam, and therefore it might be tried. One fact must be borne in mind: that there is a smaller rainfall in Uganda than in any of the major tea areas in the world, and that water supply seems to be a limiting factor to our production of tea. While shade trees may diminish the loss of water from the tea bushes, yet they also diminish the water content of the soil. It seems probable that *Albizzia stipulata* will take more water out of the soil than will *Grevillea robusta* at the same spacing, and this is another argument in favour of the latter. It is difficult to devise satisfactory replicated experiments to test the effect of shade on tea or coffee, except on a large scale (although a most ingenious experiment, using small hexagonal plots with a shade tree in the centre of each, has been started at Tocklai), but it would be well worth while for each estate in Uganda to make observations on the effect of shade trees under local conditions by arranging adjacent blocks of tea under *Grevillea* shade, *Albizzia* shade (both trees at a spacing of sixty feet), and no shade at all.

Estate Planning

Pressure on land is not yet so intense in Uganda as in some tea-growing countries and therefore it is possible to exercise some discrimination as to what areas should be planted and what areas should not be planted. It is a great mistake to plant on unsuitable soil, for tea should be a long-standing crop; it is expensive to establish, and nobody would willingly abandon an established block, however unsatisfactory its growth. Moreover, the area of new land which may be planted with tea is restricted.

According to the old-fashioned textbooks, tea will grow only on soils more acid than those on which it flourishes in Uganda. These books were founded on experience in North India, where, if reaction of a soil approaches neutrality, it usually contains an appreciable amount of calcium, and the dislike of the tea plant for calcium has been confused with a liking for very acid soils. In Uganda, as in South India, tea flourishes on soils which are more nearly neutral (pH 6.0 to pH 6.5), because these soils do not contain much lime. Bracken is often regarded as a plant whose growth indicates that the soil is suitable for tea, and this is true to some extent, for the plant is seldom seen on alkaline soils; but on the other hand bracken and other ferns may be abundant on very poor acid soils, whose content of plant nutrients is so low that the growth of tea will fall off a few years after planting. In the wetter districts of Uganda, where the climate is suitable for tea, the secondary growth of vegetation on good soil consists of forest or elephant grass (*Pennisetum purpureum*), and it is better to make clearings for tea only on such land rather than on land under shorter grasses such as *Cymbopogon afronardus*, which grow on poorer soil. In the Toro district, tea planted on short grassland has not grown nearly so well as that planted on elephant grassland nearby. Elephant grass, however, must not be regarded as an infallible indicator plant for tea, for it grows also in volcanic areas on soils rich in lime.

With the exception of volcanic calcareous deposits in the Toro district, none of the soils in the tea-growing areas of Uganda seem to be naturally too alkaline for the successful cultivation of tea. In South India, on the other hand, there is a much greater range of soils, and some have proved to be too alkaline for tea. One estate was seen on which Robusta coffee was flourishing but on which tea had failed. It is interesting to note that some of the Arabica coffee estates whose produce is of high liquoring quality have soils much more alkaline (pH 8) than most of the land on which coffee is grown in Uganda.

Uganda has been relatively densely populated over a long period and sites of old settlements are scattered over the areas where tea is grown. Even when all trace of the settlement above ground has disappeared for many years, the soil continues to be different from that of the land around; often it is more compact, while usually it is neutral or alkaline in reaction, and there is such an accumulation of bases (especially of calcium) that tea will not grow. Many of the bad patches to be seen on Uganda tea estates are due to these old house sites; often the circular outlines of the huts are perpetuated by the shape of the blank spaces in the tea bushes. It is essential therefore to avoid the sites of old settlements whenever other land is available. Local tradition often will indicate where the houses have been; sometimes quantities of broken potsherds may be seen in the ground, and almost invariably the reaction of the soil is more alkaline than that of the earth nearby.

Where house sites do occur in blocks of tea, steps may be taken to cover the bare ground. One method is to plant groups of shade trees in them. *Grevillea* would be useful for this purpose, especially as there is some evidence that its dead leaves are rich in soluble alumina and therefore may render the soil more acid. Sometimes tea plants may be established by using heavy dressings of nitrogenous manures, for it seems that the proportions of the elements present in the soil are more important than the absolute amounts in their action on plant life, and the addition of nitrogen to the soil may counteract the excess of bases. Sometimes large holes may be dug and filled with other, less alkaline, soil, while the Soil Chemist of the United Planters' Association of Southern India has obtained evidence that heavy dressings of sulphur (at the rate of 1,200 lb. per acre) may render the soil of house sites sufficiently acid for the growth of tea.

If an orderly lay-out of an estate which will facilitate economical working is to be secured, it is essential that a topographical and soil survey should be made before planting is commenced. The land most suitable for tea, up to the acreage allotted, should be selected; the remaining land can be put to other purposes, discussed below. The need for a comprehensive planting scheme is equally important, whether new land is being opened up or whether an estate is changing over from coffee to tea. On no account should tea be interplanted among coffee; unless the coffee is removed first, the land cannot be cleaned, the lines of bushes will not be straight, and the tea will make poor upright growth instead of low spreading frames.

A road system must be planned, to allow quick access to all parts of the estate for easy supervision and for lorry transport of manures to the tea (cotton seed, a most valuable manure, sometimes can be obtained in Uganda for little more than the cost of transport, but the cost of application is greatly increased if it has to be carried any distance); while in the case of tea at a distance from the factory, much better plucking can be secured if a lorry is sent to fetch the leaf rather than if the labourers have to carry it into the factory. In addition to the roads, narrow paths should be left to divide up the tea into blocks for convenience of working. It is tiresome to deal with a number of small patches all requiring different treatments, while it is difficult to supervise labour on large stretches of tea. Ten acres is a size which will be found suitable for allocating of tasks to a gang for weeding, pruning and plucking and for recording the yields of leaf. Unless this system of roads and paths is considered before planting commences, difficulties will ensue, for it requires a strong mind to remove established tea bushes in times of restriction.

Land on which tea does not grow well can be put to other uses, one of the most important of which is the growing of fuel for the tea factory. We are not fortunate in Uganda in having supplies of coal and oil at hand for our factories, as is the case in Assam, and wood fuel must be used for the driers. However, there is usually plenty of land available on which suitable trees, such as *Eucalyptus robusta* and *E. saligna* can be *planted and, as* these grow rapidly here, ample supplies of fuel can be secured if a comprehensive fuel-planting programme is carried out. Steam-heated driers are proving most satisfactory in North India, and as they can be worked in part by the waste steam from an engine, it might be worth while to investigate the economics of all-steam factories, for the extra trouble of cutting fuel might be off-set by lower maintenance costs with steam engines than with oil engines and by independence of imported supplies of fuel.

Last but not least, the amenities for the labour force should be considered when an estate is laid out. If land is available, it is well to arrange that each family can have a plot of ground on which to grow their food. The same consideration applies to the African. The large and prosperous tea firms of India have spent much money on staff welfare, and the result is that the labour employed on estates seem much better off, both as regards financial status and living conditions, than the majority of peasants in their own villages. As a result, in spite of the efforts of agitators, very happy relations generally exist between employees and employed.

A settled labour force is a necessity on a tea estate—so much of the work like pruning and plucking requires considerable training—and measures to promote the well-being of the labour are not only humanitarian but also good business.

Stability is a great feature of the tea industry of India; much of the production is from the properties of large companies, whose organization is often almost as elaborate as that of a Government department. But there still flourish many private estates whose owners and whose employees belong to the same families as when they were started forty years or more ago. We can learn much from the practices of tea planters in other countries, but we shall also have to experiment with tea to find out what are the best methods for Uganda. Thus there may be built up in East Africa an industry as stable, as prosperous, and as magnificently hospitable as the tea-planting industry of India.

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GAUGING STREAMS AND FURROWS

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Apart from special methods requiring more or less permanent installations of measuring apparatus, such as gauging weirs or Venturi meters, which will not be discussed here, there are five main methods of stream gauging.

These are as follows:—

(1) *By Current Meter.*—This method is applicable to all but the smallest streams, and is the only possible method in large rivers.

(2) *By Rod Floats.*—This is especially useful in gauging regular channels or furrows, and is only approximate if the bed of the stream is irregular.

(3) *By Surface Floats.*—This method is only approximate, but is very rapid and is sufficiently accurate for most farm purposes.

(4) *By a Notched Board.*—This method is only applicable to small streams or furrows of up to 1 cusec.

(5) *By Volumetric Measurement.*—This is only applicable to very small flows, but if carefully done is very accurate.

Soundings

The first three of the above methods require a knowledge of the cross section of the stream channel. In the case of Method (1), only one cross section is necessary as the velocity of the water at the actual position of the cross section is measured by the current meter. A point on a straight stretch of the stream or channel should be chosen where the flow of the water is smooth and parallel to the banks and not turbulent, and where the banks dip abruptly into the stream, so that there is little or no "dead" water.

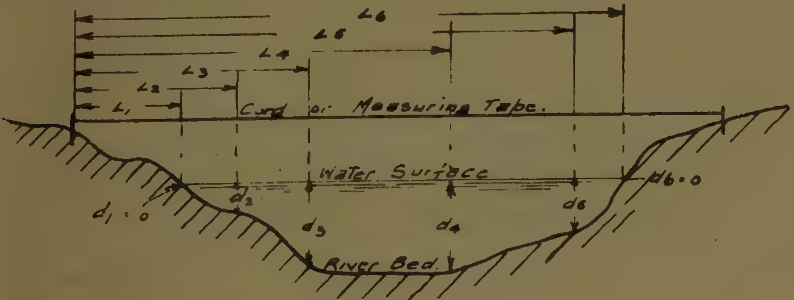

Fig: I
Cross Section of Stream.

In the case of float measurements (Methods (2) and (3)), it is necessary to find as long a straight stretch as possible of the stream over which the shape and fall do not vary considerably, and cross sections should be taken at either end and in the middle of this stretch. The length of this measuring stretch should not be less than 50 feet, but it is better to have a short stretch of even cross section and velocity than a long one with varying cross section and fall.

With streams of no great width the simplest method of measuring a cross section is to stretch a measuring tape across from bank to bank. A cord or rope with tags tied to it at known intervals may also be used, and can be tied to convenient trees or to stakes driven into the banks. The depth of the water is then measured at intervals across the stream, the distance from one bank and the depth being noted together.

The shape of the river bed can then be plotted as shown in Fig. I and the area of water passing the point can be calculated.

So long as the depth does not exceed 10 ft. (more or less), a sounding pole is used, which has marked on it feet and inches reading from the bottom upwards, and which should have a flat base so as to prevent it sinking into the softer parts of the stream bed. A length of $\frac{1}{2}$ in. diameter water piping, to the foot of which a flange is screwed, makes a very suitable sounding pole. The measurements can be marked by file cuts which then cannot easily be rubbed off or defaced. For depths exceeding 10 ft. a sounding line with a weight has generally to be employed. This is usually a hemp cord graduated into feet by tags of leather or cloth inserted between the strands of the cord. For velocities up to 4 ft. per second a weight of about 4 lb. will be sufficient; a cone-shaped piece of lead is the best, but a 4 lb. hammer-head makes quite a suitable substitute if lead is not available. For rapidly flowing streams soundings made with a light weight usually over-estimate the depth, and a torpedo-shaped sinker of much greater weight becomes necessary.

Having obtained the cross section of the stream the velocity of the flowing water is obtained at as many points as possible across the stream. By multiplying each of these velocities by the area over which it is supposed to occur and by adding these results, the total flow of the stream at that cross section is obtained. If the areas are measured in square feet and the velocity in feet per second, the discharge is given in cubic feet of water per second or "cusecs". One cusec or cubic foot per second is equivalent to 374 gallons per minute, approximately 22,500 gallons per hour, or 540,000 gallons per day.

We will now consider the various methods of measuring the velocity of the water. In all streams and channels the velocity of the water varies both from the centre to the sides and from the top to bottom. The more regular the shape of the channel and the smoother its sides and bed, the smaller is this variation, but no channel has a completely uniform velocity throughout. Fig. II shows a typical river section with velocity contours. It will therefore be seen that the greater the number of observations, both in the horizontal and vertical planes, the more accurately the final discharge can be measured.

With a current meter, Method (1), velocities at any point can be obtained and a clear picture of the variations made. Rod floats, Method (2), will give a close approximation to the average velocity in each vertical section. Surface floats, Method (3), however, only give the surface velocity at points across the section.

Method (1), *by Current Meter*

There are a number of makes of current meter in the market, but in all of them the essential portions are a propellor or screw, which is set in rotation when the meter is immersed in moving water, and a counting apparatus which records the number of revolutions made. Current meters will have been rated by the makers, but may easily be checked or re-calibrated by moving them at a known velocity through still water.

For shallow streams, the current meter may be fixed to a rod similar to a sounding rod—in many cases the sounding rod itself is used—or for deeper water it is hung from a cable, and below it a heavy torpedo-shaped weight is suspended to keep the line as vertical as possible.

When the cross section of the river has been determined by soundings, the measuring tape or cord is left in position and velocity readings are taken at as many positions across the stream as may be required. At each of these positions across the stream a number of readings at different depths must be taken if accurate work is required. If, however, only approximate results are required or where the depth of water is not excessive, one reading only at a depth below the surface of 0.6 of the water depth at that point will normally give the average velocity in that vertical line. Fig. III shows graphically the results obtained from this method.

The total discharge of the stream will be the sum of V1 × area *a b c* + V2 × area *b d e c* + V3 × area *d f g e* + V4 × area *f h k g* + V5 × area *h l k*, in cubic feet per second where V is in feet per second and area is in square feet.

The number and position of the readings taken will depend on the shape of the river bed and on the rapidity with which the velocity changes across the section.

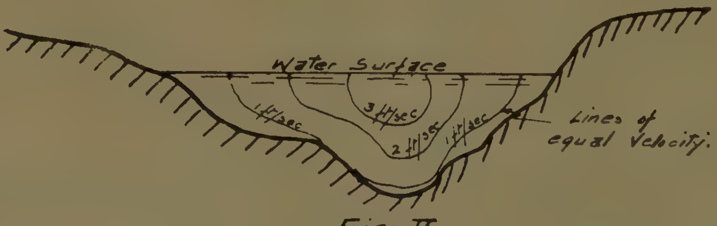

Fig: II

Cross Section with Velocity Contours.

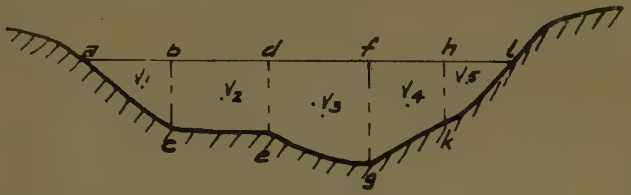

Fig: III
Velocity - Area Diagram.

Method (2), *by Rod Floats*

The best form of rod float is a watertight tin tube, about ¾ in. in diameter, weighted with shot so that it floats vertically. To get the most accurate results the float should show as little as possible above the water, so as not to be affected by the wind, and should be as nearly as possible equal in length to the depth of water. It will be seen therefore that this method is not very suitable for river sections where the depths may vary, but is better adapted for use in canals of uniform depth and section, and rod floats are seldom used except for measurement of canal flows.

As stated earlier, three cross sections are required, and the mean of the three is taken; a distance is measured out along the bank and a mark or stake placed at either end of this measured distance. The float is placed in the water some little way up-stream of the upper mark and the time that the float passes the upper mark is noted and again when it passes the lower mark. The distance in feet, divided by the difference in the above times in seconds, gives the velocity in feet per second. At least five floats should be taken in each vertical section and the mean of the results taken.

The velocity given by the float very closely approximates to the average velocity in each vertical section, and the calculations for the total discharge are therefore the same as those for current meter measurements as shown in Fig. III.

It will often be found that the float does not always remain in the line of the vertical section chosen, and any floats which tend to wander during the run should be eliminated, and the mean of five good runs only be taken.

Method (3), *by Surface Floats*

As previously stated, this is only an approximate method, but it is quick and can if necessary be carried out by an observer by himself.

In order to avoid wind effects it is best to use globular floats. Where a supply of oranges is available, they form ideal surface floats and have the great advantage that they can be thrown to the desired position with fair accuracy.

As the surface velocity of a stream is greatly affected by wind and bends, it is very difficult to get a surface float to remain in any particular vertical section, and particularly in a narrow fast-flowing stream it will be found that the float will tend towards the centre of the stream even if started off at the side. In a broader slower-flowing stream it should be possible to get a fair number of floats to remain fairly closely within the desired lanes.

The average velocity in a vertical section lies between 0.8 and 0.9 of the surface velocity of that section, depending on the nature of the river bed. For gravel and boulders the lower figure should be used, and for fine smooth sand the higher figure. For the average stream or furrow a figure of 0.84 will give reasonably accurate results. The method of measuring the velocity of the surface floats is the same as for rod floats, and the calculations are the same except that each recorded velocity is multiplied by the factor to reduce surface velocity to the mean velocity in each vertical section.

For small furrows and small streams it will be found practically impossible to do more than measure the velocity in the centre of the stream, nevertheless a fair approximation of the actual flow may be obtained by this method. As for rod floats, three cross sections should be taken on a suitable straight stretch of river and the mean area of these three sections taken as the area of water passing down that stretch. Floats should be thrown or placed in the water as near the line of maximum velocity as possible and timed, as explained previously, over a measured distance. As large a number of floats as time permits should be used and, discarding the results of floats which have not run true down the stretch, the mean of the results should be taken.

From current meter measurements taken on a very large number of furrows and rivers, I find the following relationships between maximum surface velocity in the centre of the flow and average velocity over the whole section:—

Type of water.	*Average Velocity. Max. Surface Velocity.*
Rivers with irregular and bouldery beds	0.60
Rivers with smooth beds and little side growth	0.70
Large furrows (over 2 cusecs)	0.70
Small furrows, in good order	0.80
Concrete-lined furrows	0.90

Therefore, having obtained the surface velocity of the centre of the stream or furrow, and having decided under which type the water being measured falls, the measured maximum surface velocity is multiplied by the appropriate factor to get the average velocity for the whole section. This is then multiplied by the mean area of the three cross sections and the result is the discharge of the stream or furrow.

It should be realized, however, that this method is only approximate, and errors of 15 to 20 per cent may be made.

Method (4), *by a Notched Board*

This method is very accurate, provided the conditions are suitable. There are various forms of notched weirs, but the simplest and most accurate is a 90° V notch. The best notch is one cut from a steel plate, but this is heavy and not very easily transported, and for all ordinary purposes a section of 1 in. planking 4 ft. long and 2 ft. deep, with a 90° notch cut 12 in. deep in the centre of its upper edge, will serve. The edges of the notch must be bevelled at 45°, the sharp edge of the bevel being placed up-stream. Care must be taken in the cutting of the notch to see that it is truly symmetrical.

To take a gauging, the board is placed across the bed of the stream or furrow and banked round with earth so as to be completely watertight at the bottom and sides, and the whole flow is taken through the notch. The bottom of the V must be at least 6 in. above the bed of the stream and the filling at the sides should not approach closer than 6 in. to the edges of the notch.

The height of the still water above the bottom of the V is measured and the discharge is given by the formula $Q = 2.54\ H^{5/2}$ (*see* Table I), where Q = Discharge in cusecs and H = Height of water in feet above bottom of V.

The disadvantage of this form of gauging is that the water level in the stream or furrow is raised considerably by the placing of the notch, and in the case of a furrow with a flat grade the water is dammed back for a long distance and often overflows the banks of the furrow.

This method is only really suitable for fairly steeply graded furrows, or in a section of furrow with a deep cut. Also in a stream a narrow section must be chosen or the closing of the gap becomes difficult. In all cases before reading the height of the water the flow into and out of the dam must have reached equilibrium, and in a flat-graded stream or furrow this may take a considerable time.

Method (5), *by Volumetric Measurement*

Little need be said about this method, as it is practically self-explanatory, and merely consists of measuring the time taken to fill a receptacle of known volume, such as a petrol tin or small tank. This method is applicable to small springs where the water can be concentrated to one point and led into the measuring tin or tank.

TABLE I

DISCHARGE OVER SHARP-EDGED 90 DEGREE V NOTCH

Calculated from $Q = 2{\cdot}54\ H^{5/2}$ Q=Cusecs H=Feet

Depth of water over V in inches	DISCHARGE			
	In cusecs	Gallons per day	Gallons per hr.	Gallons per min.
½	·002	1,080	45	·75
1	·006	3,240	135	2·25
1¼	·010	5,400	225	3·75
1½	·015	8·100	338	5·60
1¾	·022	11,880	491	8·2
2	·030	16,200	675	11·25
2½	·050	27,000	1,125	18·70
3	·077	41,600	1,735	29·00
3½	·116	62,600	2,610	43·50
4	·163	88,000	3,670	61·00
4½	·222	120,000	5,000	83·50
5	·282	152,100	6,350	105·50
5½	·365	197,000	8,210	137
6	·450	243,000	10,120	169
6½	·560	302,000	12,600	210
7	·66	356,000	14,850	247
7½	·780	421,000	17,600	292
8	·91	491,000	20,450	341
8½	1·08	583,000	24,300	405
9	1·24	670,000	27,950	465
9½	1·42	766,000	32,000	533
10	1·62	875,000	36,500	608
10½	1·83	985,000	41,100	685
11	2·04	1,100,000	45,800	765
11½	2·28	1,230,000	51,300	855
12	2·54	1,370,000	57,100	950

(*Received for publication 27th August*, 1940)

REVIEWS

AGRICULTURE IN UGANDA, by the Staff of the Department of Agriculture, Uganda; edited by J. D. Tothill. Oxford University Press, 1940. 551 pp., 30 plates, 3 maps and 2 climatic charts. Price 20/-.

Many who know the handbook *Uganda*, by H. B. Thomas and R. Scott, which was published five years ago and immediately took a place of distinction amongst works of its kind, will be glad that a companion volume, *Agriculture in Uganda*, has appeared from the same press. The new work may be regarded as a technical elaboration of the agricultural chapters of the earlier one, so framed nevertheless as to be complete in itself. Together, and read as complementary to each other, they make Uganda one of the best-described territories of the Colonial Empire. The agricultural volume will be as much of a pleasure to possess as is its forerunner. It is as scrupulously edited, as beautifully printed and illustrated, and the variety and interest of its subject-matter is as fully deserving of the high standard of treatment.

About three years seem to have elapsed between the writing and the issue of this volume, revision in the meantime having chiefly consisted of curtailment of some of the technical detail. Because of this delay, some of the chapters may contain matter that their respective authors could now improve upon, and certain very recent developments are not described. But most readers will not be concerned to insist on a stop-press quality in such a book. They will only be grateful that the intention to publish has persisted through the difficulties that overtook the project. It is safe to predict that the demand for the book from outside Uganda will be such as to give early opportunity for re-issue when times improve, and the further advances will by then have been consolidated. By then, too, we hope we may look forward to the balancing up of Tanganyika's excellent handbook of 1930, which is overdue for revision, by an agricultural new testament of similar kind, and perhaps Kenya will grow discontented with an official silence about itself in the way of handbooks and will employ what must be its abundant material in the issue of volumes of the same quality. East Africa will then have done what it should to claim the attention that is its due from the English-reading public at large, and it will have done so on the proper basis that amongst its unique variety of interest as a tropical region, nothing is more worthy of comparative study than its agricultural practices and progress.

It is right to recommend that the new work be read against the background provided by the general handbook, but on its own subjects *Agriculture in Uganda* is self-contained. It records the developments during "the period commencing with the completion of railway construction from Mombasa to Kisumu [on 20th December, 1901] and ending in 1937". In the days of head-porterage before the railway came, no agricultural product could stand the cost of transport to the coast, and the story since that date is therefore that of the whole period of emergence from almost total isolation to a position of importance in world trade; from a kind of primitive autarchy in which very simple needs were satisfied entirely from local resources, to the possession of a large monetary spending power earned almost solely from a greatly developed agriculture. Much that was original practice before the period of European influence still survives, with or without adaption, as part of the present-day agricultural routine; much that was undreamt of as within the capabilities of native Africans has been introduced, adapted, modified, taught, learned and become customary. The new generation already accepts the mixture as its tradition.

Such a record will interest a great many students of tropical agriculture who do not necessarily seek information about Uganda, *qua* Uganda. They will be those who have turned with profit in recent years from the older general textbooks to regional accounts of the subject in particular geographical settings. Of these we have in mind especially Faulkner and Mackie's *West African Agriculture* (1933) and the more impersonally compiled *Outline of Malayan Agriculture* (1936). The present account, from a third distinctive region, will be found refreshingly different. Like the *Outline*, it embodies the experiences and accumulated observations of a numerous departmental staff, but like Faulkner and Mackie it is personally communicated. Every chapter is signed, indeed every section, and the reader takes due notice: "Ha! *X* speaking. Now *X* is a fellow to pay attention to on this subject." It will be found also that many of the crops treated of in this book are discussed more informatively than in either of the other two, while the volume owes little of its bulk to the reproduction of standard descriptive matter, which is left to be sought in textbooks and monographs. The axioms, definitions and theorems (as it were) are taken as read. Here we have a collection of riders, applications and worked examples. Did we not, at school, learn more of our maths. from the problem papers than from the formal propositions?

Whether or not this was a deliberate plan for the book, its working-out can be followed both in the general introductory parts and in the long series of crop chapters that make up the rest. In Uganda, crop plants are not rarified botanical entities; they are sown and reaped by people, upon land. Land forms part of landscape, makes up valleys and hillsides and natural provinces, has weather above it and rocks below, consists of soil, was won from forests and bush, is held in various forms of tenure. Its fertility sustains life and was the basis of a simple economy; expansion of that economy is developing a fuller life and a civilization. But the land is an entailed inheritance and must be kept from wastage; there is much still to learn in making the higher standards of production permanent and there are not yet teachers enough to teach what is already known. Those, essentially, are the themes of the editor's Introduction (which we could have wished longer) and of the first six and two concluding chapters. A short account of the apparatus of agricultural development (the experimental stations) is given, and then the problems are worked out crop by crop. First, as is fitting, the crops that fill the belly and provide conviviality: the bananas, the roots, the cereals and the pulses. Then those that fill, transitorily, the pocket, and thence the tradesmen's tills and the Treasury: chief of all cotton, pre-eminent and developed to its strong position as principal export by programmes of research, organization and legislation, of which, in eight chapters, the story is fully told. Then coffee, which has had its ups and downs and at the worst sustains the spirit by faith, hope and controversy. Then the sugar in the cup and the tea to flavour it with, and that other creature-comfort of the modern African, the tobacco for his cigarette. Rubber earns a chapter on behalf of the planters who have persevered with it through lean times and are at length, it would seem, in the way of reaping some reward. The minor garnishings of the material life are noticed, the spices and condiments, fruits and vegetables, baskets and string. The eye lights on the surprising statement that "three Italian queens were imported by air mail", but perceives that it is in a chapter on bees. There is short treatment of cover crops, shade trees and weeds, and there are two indexes, one to the scientific names, and a general index which needed more sub-headings if it were to be really useful, as the reader will find if he tries to turn up a reference to some particular point in, say, cotton. The whole is told, we regret to say, with unbroken solemnity. The authors of *Uganda* took an occasional discreet dig at somebody, and even quoted from the Poet Laureate of their day, but *Agriculture in Uganda* is a serious affair, plain prose.

The above brief synopsis may be rounded out by reference to the treatment of two important matters not yet mentioned, the pests and diseases, and the cattle.

Each chapter that describes a crop concludes with accounts of the pests and diseases that may infest or infect it. For cotton, we have sixty pages of them; for coffee, forty-five; altogether the sections on these subjects occupy about 150 pages, or more than a quarter of the book. To some readers this proportion will seem large, but an editorial explanation defends it; much of the material, especially the entomological, is published for the first time and represents twenty years' careful work whose results it was thought appropriate thus to gather together and make permanently accessible. We suppose all tropical countries undergoing rapid development have to pass through a period when the scientific work most highly thought of and given fullest support is that devoted to plant-protection problems. Intensive attention has no doubt to be bestowed upon these in the first years, in order that the newly introduced crops and improved varieties shall be put into a sufficient state of defence for more constructive kinds of investigation to become possible and fruitful. In Uganda the departmental staff in the plant protection branches has evidently made good use of their opportunities in this phase, which we deduce, from the full treatment of the subject that has been found possible in this book, to be now past its peak.

The reviewer, not being qualified to appraise the entomology and plant pathology as such, confesses that he found himself reading a good deal of it as natural history lucidly presented. Probably many not expert will in a similar way find the chapters on geology and soils taking their attention, on their merits as attractive short sketches outlining the foundations and agricultural physiography of the country. The analysis of the nature of the soil erosion problem in Uganda is especially interesting, and this and the succeeding chapter on manures and mulching (both by W. S. Martin) are amongst the most thought-provoking in the book.

Mention of the more constructive kinds of agricultural development brings us at length to the cattle. Cattle are to be found in *Uganda*[1] but hardly at all in *Agriculture in Uganda*. The statement remains true if the italics are dropped, and it is the explanation of what might otherwise have been complained of as a lack of balance in the book we are reviewing, which treats almost exclusively of plant industry. The fusion of stock management with crop growing is a phase of agricultural development upon which Uganda has hardly yet entered; no doubt it will increasingly absorb the devotion of the Department's staff now that so many of the problems of the first stages, of which this book is the history, are solved or are in train for solution. There are already signs: the plough is established in popularity (perhaps too firmly), the pastures and grasses are being studied, there are experiments in the use of silage, and some of the work at Ngetta and Bukalasa Farms is orientated in this direction. But in this volume one misses an editorially written chapter towards the end reviewing the agricultural system that has pieced itself together crop by crop through the book, concluding that it needs more assurance of permanency through the adoption of long-term principles, and sketching for the future the lines of desirable further development with live stock fully participating.

Three minor criticisms are offered, to be taken seriously or not as the reader pleases. In the meteorological chapter we should like to have been given metric equivalents, as well as the inches and Fahrenheit degrees which this truly British Protectorate has *in the twentieth century* been taught to prefer. The East African Meteorological Service, whose Director writes this section, seems not to have the courage of its part-time convictions in the matter in question, for its first-order station for Uganda at Kololo Hill has always reported in metric units. As two of Uganda's neighbours, Tanganyika and the Belgian Congo, are accustomed to think in millimetres and Centigrade, the former thanks to the enlightened practice of the B.E.A.M.S. itself in continuing earlier usage, comparisons would have been much facilitated if those units had been employed. Then we looked in this chapter at least—they have been ashamed to confess to it anywhere else—for mention of that distinctive but deplorable feature of the Uganda agricultural atmosphere, the murk of burning cottonseed at ginning time. Finally, the writer of the chapter on Government agricultural stations has inadvertently omitted reference to the one that Uganda shares with her sister territories, the East African Agricultural Research Station at Amani.

A review would be incomplete without mention of the excellent photographs, which add much to the enjoyment of the book. In the choice of illustrations, as in other ways, this and the general handbook add to each other's value. Thus the plates in the agricultural volume showing cotton fields, cotton–banana landscape, and cotton pests, are complementary to those showing head-porterage of seed-cotton to market, and a cotton ginnery, previously published in the other.

In his introduction, Dr. Tothill makes acknowledgment, which has evidently been very fully earned, to the members of his departmental committee for the book and especially to its chairman, Mr. C. G. Hansford. Of the twenty individual contributors, A. S. Thomas, botanist, has written sections that total nearly a quarter of the text and has furnished a majority of the photographs.

G. MILNE.

A SWAHILI–BOTANICAL–ENGLISH DICTIONARY OF PLANT NAMES, by P. J. Greenway, F.L.S., Dar es Salaam; Government Printer; pp. 308; price 4/-.

This is a second edition of the author's *Swahili Dictionary of Plant Names*, published in 1937, and it is most gratifying to note that a second edition has been called for so soon by the popular demand for a book which obviously meets a long-felt want.

Excellent as was the original work, this is altogether bigger and better. It is now arranged in two parts; Part I gives us the Swahili names in alphabetical order, with a full identification of the plant so named, and in many cases a note of its use; Part II gives all the botanical names occurring in Part I, together with such popular names in English as are current, and their Swahili equivalents, thus forming a very satisfactory index to the first part.

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[1] See Chapter XIII of that book, "The Native and his Livestock": "The natives of Uganda have not yet adopted any systems of farming in which the keeping of livestock is an integral part of their agricultural organization." Turn to the earlier volume also for illustrations of the breeds of cattle.

Not only is the whole of Part II new matter, which must have entailed a great deal of work in compilation, but, forming as has been said an index to the whole, it far more than doubles the value of the original work for the ordinary reader. Part I, which represents the original book, has here been enlarged by no less than eighty pages—not quite doubled, but very nearly so. There are also included ten plates, which in a simple but adequate manner illustrate the meaning of such terms as *Ensiform*, *Pinnatifid*, *Bracteate Raceme*, and so forth.

Mr. Greenway repeats his request for "the active assistance of all those who are interested" and acknowledges the help he has already received in this way from his correspondents. We wish here to underline this request, and to point out that many people will no doubt be able to suggest one or two more Swahili names which might be included even now. Every little helps.

The Government Press have done their part well. The book is a handy size for the pocket, excellently printed, and pleasant to read; and though in bulk more than twice the size of the original volume they have only found it necessary to increase the price by one shilling.

A. B. HELLIER.

CORRESPONDENCE

Mwanza, 17th April, 1941.

The Editor,
E.A. Agricultural Journal, Amani.

Dear Sir,

Allow me a few comments in connexion with the article "Nutrition and Native Agriculture in East Africa" in your issue of January, 1941.

Sugar cane is of great importance in East African native nutrition. Thousands of tons are chewed every year. Here the retail price ranges from 5 to 10 cents for a full length cane. Last year one retailer took in Sh. 110 at the Shanwa cotton market. This "fruit" is seldom mentioned by those who list banana, papaya, mango, orange, and other fruits not nearly so common or popular as sugar cane.

Two vegetables, not mentioned by the authors, are relatively common among the natives: the eggplant (*biringanyi*) and *bamia*, called okra and gumbo in America. Americans like both, and miss them in the hotels and restaurants of British East Africa. In remote villages of Tanganyika I have found many varieties of eggplant doing well under the usual discouraging conditions. Some are globular and snow-white; some thin, snaky, and purple black; some look dangerously like common poisonous solanum. All are good eating. Boiled and seasoned with the juice of limes or green tamarind pods they are an excellent *kitoweo*. *Bamia* will thicken and give body to a mass of green leaves.

Then comes a long list of wild fruits consumed in great quantities by children and grown-ups, in season. Several, like *mfuu* and *sungwi*, are sold regularly in the Mwanza market. At this time, the skins of a wild fruit called *syeka*, and the stones of *manazi* (Parinum) litter every path on Ukerewe Island, as do Strychno shells in Ufipa. And there are many more to help native nutrition along—and my nutrition, too. But sugar cane comes first. What may its nutrition value be in modern scientific terms?

Why pawpaw instead of papaya for *Carica papaya*? It is called papaya everywhere by everybody, except some Britons. Kiswahili has *papai*. My Webster Dictionary makes a useful distinction between papaya for *Carica papaya*, and pawpaw for *Asimina tribola*. Why not get together so we are sure of what we are talking about.

Yours truly,
M. J. FORTIE.

[*Note*.—As a "fruit" sugar cane contains little of value, apart from sugar; its Vitamin A and C content being negligible compared with such fruits as the mango, guava and papaw.

The name papaw, not pawpaw, is the common one by which *Carica papaya* is known to Britons in the tropics, and it has prior claim to this name, which is found in literature as far back as 1598. There is little danger of confusing it with the American pawpaw (*Asimina tribola*), which is a temperate-region tree of a very different type. The name pawpaw for *Asimina tribola* was first used *circa* 1760.

As pointed out by Mr. Fortie, eggplants and okra are valuable items of native diet, and for this reason it is unfortunate that botanical knowledge is lacking regarding some of them, as it is in the case of numerous African cucurbits.—ED.]

SOME NOTES ON PASTURE RESEARCH IN SOUTH AFRICA

During a recent visit to South Africa I was privileged to visit certain of the pasture research centres in Natal and the Transvaal. The importance attached to pasture research in the Union can be judged by the fact that not only is the work carried on directly by the Department of Agriculture at its numerous pasture research stations, but in addition the Universities of Pretoria, the Witwatersrand, Capetown and South Africa receive special grants from Government for grassland research, while the several schools of agriculture also carry out pasture investigations. The headquarters of this research are at Pretoria, where the soil erosion and grassland research carried out by the Department of Agriculture and the University of Pretoria is most impressive, but perhaps of too elaborate a type for our present urgent needs in East Africa. The work is administered by a Grassland Research Committee, on which are represented grassland research, agronomy, botany, chemistry, economics, and animal husbandry, while the control and supervision of each of the numerous experiments at the University farm is vested in a small executive sub-committee. It is claimed that the organization of research on this basis ensures perspective and co-ordination.

As the main factor limiting stock farming in South Africa is the amount of winter feed available for cattle, it is not surprising that the major pasture problem under investigation at Pretoria University is the production of regular and adequate feed throughout the year and the utilization of the land without impairing future production. The approach to this problem is through the investigation of those resources already available. The co-ordination of the findings of the many experiments now being carried out will be a large undertaking, but should result in the laying down of efficient systems of management. The results obtained up to the present are useful mainly for the preliminary work of pasture evaluation. For instance, Rhodes grass, I was told, has been found to make excellent summer grazing, good hay, and fairly good winter grazing; mowing improves it, but hard grazing it will not tolerate. The duration of its economic life is three to four years, after which it should be re-established. The value of Rhodes grass on a farm where veldt grazing is also available lies in its use as a hay grass for winter keep. Woolly Finger grass (*Digitaria* sp.), on the other hand, is best grazed, as it is not highly suitable for hay.

The study and management of single species such as the above are comparatively simple compared with the study of veldt, where the herbage consists of a complex of grasses and other plants of differing requirements. The selective grazing by stock adds to the complexity of the problem. The results of veldt experiments are gradually supplying clues to a better understanding of the art of veldt management, and it is becoming increasingly obvious that a period of rest during the active growing season is necessary to maintain the vigour of the sward. This of course necessitates controlled grazing and fencing. It is here that the movable electric fence plays an important role in experimental work and permits the pasture to be grazed intermittently in sections small enough to provide only a few days' moderate grazing. Stock is thus kept moving from strip to strip, returning to the first section as soon as sufficient fresh growth has been made. In this way the grazed portion is kept in a young and nutritive condition, and the "sour" grasses, which are unpalatable only when old, are kept short and are not allowed to develop into the coarse tufts that result from selective grazing. The neighbouring unfenced area is mown for hay, free grazing being allowed on the aftermath.

The results of manurial experiments at the Pretoria University farm have shown that a better response is obtained from established pastures than from veldt, which is incapable of using artificial manures to the best advantage. The application of fertilizers here has its greatest value in improving total production rather than in increasing mineral content.

At the Rictondale grass introduction station, Pretoria, there is an excellent collection of East African grasses (half cut, half left to seed) which it would be hard to match in East Africa itself. Many of these were collected by Dr. Pole-Evans when he visited Kenya in 1938 to advise on soil conservation and the regeneration of grasslands. The collection of *Digitaria* spp. and varieties (approximately thirty) found at different elevations in East Africa are most interesting material for study, as are the young Elephant grass seedlings from Uganda, one with a leaf-blade two inches across. The celebrated Giant Star grass, collected near Lake Lutoto, Uganda, was on view, and certainly made a most impressive sight, growing alone. Unfortunately, it is said to have caused poisoning in cattle, so that its distribution to farmers has now been discontinued.

The grass breeding station at Prinzhof was also visited, but no breeding was in progress at the time of my visit in winter. A large number of strains of Rhodes grass have been established at this station, some of which promise to be longer lived than usual and suitable for permanent pasture.

The University of Potschefstroom, like Pretoria, devotes much of its extensive university farm to grassland research, largely veldt management and grazing trials of introduced grasses. One general conclusion reached as the result of this research is that cattle can be kept in condition throughout the year, provided that an adequate quantity of good quality veldt hay is made during summer. As the yield of such hay (valued at 25/- per ton approximately) is often only 400 to 500 lb. per acre, the area set aside for haymaking should be considerable.

The results from an experiment to study the effect of burning, singeing, cultivation and fertilizing on grass growth showed that the highest yields (in cut grass) were obtained from the fertilized plots and the next highest from the untreated controls. However, the increased yield from the fertilized plots did not pay for the cost of the treatment, which leaves the untreated plots best from the farmers' standpoint, and the moral, don't burn. In the time-of-burning experiment, i.e. in spring, summer (if not too wet), autumn and winter, the results indicated that spring burning was least harmful, but even this should be avoided if mowing is possible.

I found at Potschefstroom a firm belief in the value of the best indigenous grasses and less enthusiasm than usual for the exotics, which usually only flourish with good soil and rainfall.

The famous Onderstepoort research station near Pretoria, although now perhaps best known for its veterinary research, has in the past done great pioneer work for pasture research, some of its classical experiments having led to the efficient control of several animal diseases in South Africa caused by deficient or poisonous pastures. Pasture research has now been handed over to the pasture research division of the Department of Agriculture, but work on closely related problems is still carried on; for instance, the studies of the phosphorus and protein content of South African grasses and hay. I was particularly struck by the splendid facilities for research at this station, which owes so much to the late lamented Empire Marketing Board. There are no less than 60 scientific workers on the veterinary research staff, apart from lay assistants.

Two of the most interesting research stations in South Africa are at Estcourt and Tabamhlope in Natal, the first in the tall-grass veldt and the second, some 20 miles distant on the foothills of the Drakensberg, in typical mountain sour-grass veldt and an important water catchment area. The advantages to be gained by correct veldt management, as demonstrated at Tabamhlope, are impressive, particularly the demonstration of badly eroded land brought back to grass by the simple expedient of stopping summer grazing. Nor are the methods used beyond the means of the average farmer; they consist simply of ordinary commonsense management of the indigenous grasses based on experiment.

In a country where the annual burning of grassland is a common farming practice, it is inevitable that many of the experiments on this and other stations should concern the time and manner of burning. Some may question whether burning is necessary at all, but experience in South Africa, supported by experiment, shows that where grass cannot be removed by grazing or cutting then a light annual burning, or singeing as some anti-burners prefer to call it, is essential with indigenous grasses to reduce the bottom mat and allow the young grass through. Where no grazing, cutting or burning takes place, the grasses die out and weeds take possession of the land in a few years. The best time for burning in this summer rainfall area appears to be after the first spring rains, when the grass and soil are thoroughly damp. The worst time for burning is autumn, when the veldt is bone dry and fire not only does damage to the grass roots but also destroys animal droppings and much of the organic matter on the ground surface.

Owing to the hard frosts, which make an end of sour veldt grazing, one of the main problems in this Drakensberg area is the lack of winter keep for stock, a problem made more difficult by the fact that haymaking and the wet season coincide. This problem has been largely solved by the invention of an ingenious flue-curing hay barn, in which young green grass can be cured ready for stacking in about four to six days.

The barn consists of a central 19 ft. vertical flue, made of wire-netting on a wooden framework, from which radiate horizontal flues of wire net at different levels. There is a 15 ft. square ventilated floor, raised about 2 ft. above the ground, below which are vertical iron sheets so arranged as to direct the prevailing wind up the central chimney or flue. Green grass is thrown loosely on this floor to a depth of about 3 ft., after which ten horizontal flues are placed in position, their outer ends supported by a horizontal framework and their inner ends connected with the central chimney. More grass is then added and more flues similarly inserted until four tiers are formed and the barn is filled to the roof. As the grass heats a draught is set up in the chimney which, aided by the wind, draws air through the loosely packed fodder, removing the moisture and curing the grass. Samples of hay made in this barn were tender and green, and contained, I was told, approximately 6 per cent protein.

The Estcourt station is very conveniently situated, in that, apart from the tall-grass veldt which predominates, it also possesses areas of thorn veldt and vlei. The vlei land is largely devoted to experiments aimed at discovering the best fodder grasses for similar land on the numerous dairy farms in the district.

In the thorn veldt section a most impressive method for dealing with thorn bush was seen which deserves extended trial in East Africa, where thorn bush is competing with grass or harbouring tsetse-fly. The method consists simply of removing the soil to a depth of about 3 inches from around the base of each thorn tree and painting or spraying the trunk with a band of paraffin oil to a depth of 3 inches approximately. This is quite an original method as far as I know, and gives over 90 per cent kill. (See *East African Agricultural Journal*, Vol. 6, No. 2, p. 91, for further details of this method.)

Donga or gully reclamation is a difficult problem on which it is possible to spend unlimited sums if reclamation is carried out by mechanical means. The method evolved at Estcourt is simplicity itself, and consists of laying a single line of living sods along the lowest level of the donga so that the creeping stems of the grass (*Digitaria abyssinica*, or a similar creeping type) gradually cover the sides of the gully. It is found that the grass grows through the soil that drops from the top and sides of the gully and that no scraping or grading of the sides is necessary before planting. At the same time that the sods are laid it is necessary to exclude excessive run-off from above by constructing a graded drain and by preventing grass fires or overgrazing.

An ingenious home-made gauge was seen here for measuring the run-off from burnt and unburnt plots. The run-off from an enclosed area, about 12 ft. wide, was led to a sedimentation tank, which delivered nine-tenths to a waste outlet and one-tenth to a second tank where the water was measured and multiplied by ten to get the true run-off. One of the main advantages of this gauge was its large catchment area, which allowed cattle to graze as freely within it as on the surrounding veldt.

The Cedara School of Agriculture, situated in the sour veldt 35-inch rainfall area of Natal, is probably better known to East Africans than any other similar institution in the Union. Grassland experiments figure largely in its programme, the tendency being to turn more and more to exotic grasses, such as Kikuyu and *Paspalum dilatatum*, which flourish under the very favourable growth conditions there. The Kikuyu pastures, which approximate to 400 acres, get a very heavy dressing of a complete fertilizer annually, in addition to lime. Some of these Kikuyu pastures are remarkably productive; thus it is claimed that from one area[1] 1,000 to 1,200 lb. of butterfat are obtained per acre per annum from two Friesians or three Jerseys, with the addition of only 2 lb. of maize meal per day. Another area of 70 acres supports 400 sheep. Veldt management experiments, similar to those at Potschefstroom and elsewhere, have been carried on for some time at Cedara, and as the results from these are different from those obtained at Potschefstroom one is left in no doubt as to the necessity for treating veldt management as a local problem.

Many pleasant hours were spent with a scientifically minded farmer in Natal, whose proud boast it was that he hadn't burnt for forty years, and that he had carried out pasture experiments long before the Government had thought of them. He did, however, singe those areas that could not be mown or grazed down, but only immediately after at least half an inch of rain had fallen and not after 11 a.m. A comparison of his pastures with similar lands around him which have had what is mistakenly called "a good burn" annually, provided a convincing demonstration of the benefits derived from the intelligent treatment of grasslands, whether vlei or veldt. The growth of Kikuyu grass on his vlei land was remarkable, while in one area wild white clover had established itself in this pasture. These pastures received the following treatment annually: "scrubbing" in spring (with a wheel-less home-made road grader weighing a ton), followed by harrowing and mowing, after which a dressing of 300 lb. of nitrochalk per acre was applied in three equal dressings. Lime is a limiting factor in these vlei pastures, and no response is obtained from artificials unless a dressing of lime is given equivalent to half a ton per acre per annum. This experimenter was very insistent on the need for manuring and keeping land up to "Kikuyu standard" if this grass is to survive. When fertility drops, in comes *Paspalum dilatatum*, which in turn gives place to poorer grasses as fertility drops still further. His final dictum was that "none of the indigenous grasses are worth a damn compared with the best exotics," an opinion not shared by others if they happen to be farming poorer lands with a lower rainfall.

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[1] See comments on this in Journal for September, 1939, p. 147, column 1.

Another scientifically minded farmer friend, whose motto is evidently "science with practice," proudly showed me a really wonderful Kikuyu pasture which a few years before had been an extensive and unproductive swamp. The change had been brought about simply by erecting wire and brushwood fences at intervals across the swamp so as to catch the soil that came down with the annual floods from the surrounding hillside farms. In a few years soil had collected to a depth of three to four feet. Now that his neighbours have nothing left but subsoil to present him with, he doesn't trouble to trap their soil—wise man!

Those interested in grassland investigations in East Africa will find a visit to the pasture research centres of the Union a stimulating and useful experience, for although the plant successions of the veldt are different from those of East Africa and the complex of species much greater, yet much of the work being carried on in South Africa is applicable to parts of our highlands. The results and experience obtained in the Union should not be lost sight of when the proposed expansion of pasture research in East Africa takes place. As in South Africa, the development of our livestock industries must be founded mainly on the resources of our natural grasslands, properly managed.

A.G.H.

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A RECENT ADVANCE IN THE CONTROL OF TOBACCO MOSAIC DISEASE

It has long been known that the virus of this destructive disease can be spread extensively in the field on the hands of labourers when carrying out routine operations on the tobacco crop. Virus from a single diseased plant, or even from smoking tobacco, contaminating the hands, can be carried to many healthy ones. The practice has thus arisen of requiring workmen to wash their hands frequently when engaged in handling the plants.

An extensive series of experiments in Sumatra by Dr. van der Weij (*Med. Deli Proefst.*, 3e Serie, No. 6, 1940) has shown that the most effective material for destroying virus on the hands is a solution of 8 per cent trisodium phosphate, with 4 per cent of soap. This solution remains effective until it loses its soapy properties. Labourers should be provided with a second container of plain water in which they can rinse their hands after cleaning in the disinfectant solution.

A METHOD OF COMPOST-MAKING USED IN NYASALAND

Large quantities of compost are made by the Department of Agriculture in Nyasaland by the method described below. The description is taken from typescript sheets circulated by the Department. The annual out-turn on the Zomba Experimental Station is 400 tons, which is either used on the station, with outstanding results, or sold to native cultivators.

The object of the process is to convert a mixture of plant residues and animal waste products into a type of organic matter similar to that found in normal well-aerated soils, and to effect this transformation with the minimum loss of nitrogen. In order to achieve these objects certain conditions must be fulfilled, and the following points should be remembered throughout the process:—

1. The animal waste products must be incorporated as thoroughly as possible with the plant residues.

2. There must be an ample supply of air throughout the decomposing manure.

3. There must be an amply supply of water, since no effective decomposition can occur under dry conditions; but the water supply must be carefully regulated in order to prevent loss of aeration.

4. It is important to prevent the development of acidity, and this is inhibited by the addition of wood ashes and earth. The wood ashes also serve as a source of additional potash and phosphate (and should be stored under cover to prevent leaching of these constituents); and the earth, as will be seen later, can be conveniently used as an absorbent for urine from the cattle.

5. The decomposition depends on micro-organisms, and the ultimate product is controlled by the types of micro-organisms which are concerned in its formation. When the first four conditions are observed the correct micro-flora will automatically develop in time, but the process will be more rapid and certain if the material is inoculated with a portion of older and actively decomposing manure, which contains a large number of desirable micro-organisms. Decomposition takes place in roughly two stages—

(*a*) a rapid decomposition of carbohydrate material, chiefly induced by fungi, followed by

(*b*) a slower decomposition of nitrogenous material in which bacteria play the predominating part.

Accordingly, it is desirable to inoculate the manure at two stages in its decomposition, using appropriate material in each case. These considerations are the basis of what is now generally known as the Indore method, devised originally by Howard and Wad (*The Waste Products of Agriculture*, 1931). The process here described is the Indore method, but the quantities of the various ingredients have been actually tried at the Zomba Experimental Station with satisfactory results.

Cattle Management

The cattle pen should be situated near a supply of water, if possible. There is no reason to make the pen an elaborate affair, the only essential feature being a floor composed of a six-inch layer of powdered earth on which fresh bedding can be spread each day. This earth floor supplies a suitable resting-place for the cattle and absorbs urine. After three to four months the urine earth so formed should be removed, dried and stored for use in the compost manufacture. As there will generally be an excess of urine earth, a portion may be available for direct application to the fields, where it will be found useful as a quick-acting fertilizer on account of its high nitrogen content.[1]

Bedding for Cattle.—The bedding for the cattle is composed of all the waste products of the estate. Practically anything can be used, such as fallen leaves, green manure, weeds, etc., and these should be allowed to wither for at least two days before being stacked ready for use. All hard material may advantageously be spread on roads, until crushed by traffic, before stacking. Any woody substances, such as sawdust, wood shavings, paper, etc., though unsuitable for bedding, may be used in the compost if previously soaked for at least two days in water. The amount should be less than one-twentieth of the bedding.

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[1] When the compost-making is being started for the first time there will obviously be no urine earth available and its place may be taken by earth scraped from under the bedding in old cattle pens or, failing this, from under an old manure heap. This plan allows the composting to be started without delay and gives fairly good results.

The most satisfactory compost is prepared from *mixed* vegetable residues. No one type of residues should exceed a third of the total, and so precautions must be observed in the stacking. Each type of bedding as it arrives should be stacked as a layer, not exceeding one foot in thickness, and successive layers should be of dissimilar material. When bedding stacked in this way is being moved to the cattle pen, vertical sections of the stack should be taken, thus ensuring an even mixing of all ingredients.

Directions for Compost Manufacture

The compost is prepared in shallow pits, which should obviously be as near the cattle pen as possible. The size of the pits recommended by Howard and Wad are 30 ft. by 14 ft. and one foot in depth, the earth from the pit being built up to give a total depth not exceeding two feet.

The time required to fill such a pit naturally depends on the number of cattle, but it is important that not more than six days' bedding be used for each batch of compost. With twenty cattle a pit can be completely filled with six days' bedding, but with only ten cattle only one-half of the pit should be used, and so on. There is, however, no reason why the whole or a part of the pit should not be filled if there are sufficient cattle.

In the following directions the weights of the various materials are calculated for ten cattle. These quantities are, of course, only intended as an approximate guide, and in practice it will be found advantageous to measure the volume occupied by the various weights of materials in any convenient receptacle, and use these for future work.

The bedding is conveniently moved from the stack to the pen and from the pen to the compost pit in a stretcher consisting of a piece of canvas, 4 ft. by 3 ft., nailed to two bamboo or other poles, 7 ft. 6 in. in length. This can be easily carried by two men, and serves as a useful rough measure of the bedding used.

For ten cattle, ten to fifteen stretchers of bedding are spread on the floor of the pen each night. The trampling of the cattle helps to break up the plant residues further, and the bedding also becomes impregnated with urine.

First Day.—In the morning a thin paste or slurry is made as follows:—

5 lb. of wood ashes.
5 lb. of urine earth.
50 lb. of fresh dung from the pen.
10 lb. of material from a compost pit, ten to fifteen days old.
20 gallons of water.

This is placed in readiness beside the pit.

Any excess of dung, 20 lb. of material from a 10 to 15 days old pit, and 80 lb. of urine earth are distributed as uniformly as possible over the used bedding in the pen. The bedding is then transferred, in stretchers, to the pit, where it is spread in successive layers of about two inches in thickness, each layer being sprinkled with an aliquot portion of the freshly stirred slurry before the next is added.

When the entire day's bedding has been transferred to the pit, six gallons of water are sprinkled over the charge, and in the evening a further ten gallons are similarly applied.

Second Day.—Six gallons of water are sprinkled over the first day's charge and a new charge placed on top in a similar manner.

Third, Fourth and Fifth Days.—Exactly the same as second day.

Sixth Day.—Final charge and one-half of pit filled.

Seventh Day.—Six gallons of water sprinkled on last charge. Charging the other half of the pit is started.

Tenth Day.—Fungus growth should be well established and the temperature should be rising.

Twelfth Day.—First watering with 25 to 30 gallons.

Sixteenth and Seventeenth Days.—First turning. 60 lb. of material from a month-old pit are scattered over the surface of the compost, moistened and mixed with the top layers by raking. Half of the compost is then dug out in vertical strips and scattered over the remaining undisturbed half in thin layers, which are sprinkled with water. The total water required is 60 to 100 gallons.

Twenty-fourth Day.—Second watering with 25 to 30 gallons.

Thirtieth or Thirty-second Day.—Second turning.—The double thickness of compost from the first turning is turned back into the empty section of the pit. As before, the material is removed in vertical strips and it is then scattered over the vacant part of the pit, with the addition of about 60 gallons of water.

Thirty-eighth Day.—Third watering with 25 to 30 gallons.

Forty-fifth Day.—Fourth watering with 25 to 30 gallons.

Sixtieth Day.—Third turning. As the compost is turned it is removed from the pits and made into rectangular heaps on the surface, either between the pits or in the field where the compost is to be used. These heaps should not be larger than 10 feet at the base, 9 feet at the apex, and 3½ feet in height. 40 to 80 gallons of water should be added during this turning.

Sixty-seventh Day.—Fifth watering with 20 to 25 gallons of water.

Seventy-fifth Day.—Sixth watering with 20 to 25 gallons.

Ninetieth Day.—Compost ready for use.

Throughout these processes it is important to avoid compacting the material in any way, and to be sure that it is well broken up and mixed during each of the turnings. It is also of great importance to be sure that all water and slurry is applied evenly to the compost.

It will be seen that in order to run the process continuously with ten cattle a minimum of five pits is necessary.

Effect of Rain

The foregoing instructions apply to the making of compost in dry weather. In the event of rain the quantities of water added must be reduced and, as a guide to the reduction necessary, it may be helpful to note that one inch of rain represents the addition of about 218 gallons of water to a 30 ft. by 14 ft. pit.

During the rainy season it is advisable to abandon the pits and proceed with compost-making in heaps above ground level. In order to ensure good aeration, the dimensions of the heaps should not exceed 7 ft. by 7 ft. at the top, 8 ft. by 8 ft. at the base, and 2 ft. in height. The capacity of such a heap is approximately an eighth of a pit, and consequently two can be formed by the bedding of ten cattle in three days. The charging and turning of the heaps is carried out in a similar manner to the pits, but the amount of watering required depends on the rainfall and no hard-and-fast rule can be given. It should be noted that if the rainfall is so great as to cool the pits seriously the subsequent turnings and other operations must be delayed.

This method of composting in heaps tends to give a less uniform product than the pit method, and should only be resorted to at seasons when the rainfall is so great that the pits cannot be used.

Costs, carefully worked out in Zomba, come to slightly less than 3/- per ton.

I greatly fear that in the hurry and bustle of all this progress that is based on applied science, we have not sufficiently studied the map of our own destiny, for surely just in proportion as we manipulate nature to our own ends with increasing skill and success, so ought we to be careful to return to nature itself for our further nourishment and inspiration.

Sir George Stapledon.

. . . ANOTHER MAN'S POISON

"A warning is sounded in this article on the use of Kikuyu grass in the Auckland Province. The indiscriminate planting of Kikuyu grass in the North [Island of New Zealand] constitutes a great danger, and there is little doubt that where this grass is getting on to highly fertile country it will prove a curse and will in a very short time have a disastrous effect on production in the affected areas."

N.Z. Journal of Agriculture, November, 1940.

ANTI-TSETSE CLEARING AND LAND USE

By R. R. Staples, M.A., Dip. Agric. (Cantab.), Agricultural Department, Tanganyika

It is well known that clearing land of its bush and tree growth, providing the cleared areas are sufficiently large, is an effective means of controlling the various species of the tsetse-fly (*Glossina* spp.). In Tanganyika Territory, in particular, very considerable areas of land have been cleared of bush for this purpose, with tribal turn-outs of labour amounting to tens of thousands of men. In Singida district alone some 25,000 men for ten days each have been used for many years on anti-tsetse clearings.

Frequently, however, it has been assumed that while such clearing may be effective in controlling the tsetse, it has undesirable effects in other directions, and particularly in encouraging soil erosion and in decreasing the fertility of the soil and water supplies. These assumptions have by no means been proved, and the object of this note is to draw attention to, and invite comment on, some other effects of bush clearing. The subject is, I think, of importance, as control of bush growth seems to me, in fact, fundamental to the whole scheme of land use in semi-arid East Africa.

What therefore, in the light of our present knowledge, are the effects of bush clearing on (*a*) the run-off and soil erosion rates, (*b*) soil fertility, (*c*) stock-carrying capacity, and (*d*) water supplies?

Before attempting to discuss these, however, I wish to emphasize that my remarks apply mainly to the semi-arid conditions in East Africa, namely the dry, deciduous grass woodland and thicket zones — *Brachystegia* (*myombo*), *Combretum* or *Acacia* associations, and the thorny thicket types of vegetation so characteristic of the drier areas. These are the areas mainly affected by tsetse in East Africa and where most of the anti-tsetse clearings have been carried out.

The Effect of Bush-clearing on the Run-off and Soil-erosion Rates

These two factors are discussed conjointly as, of course, soil erosion is dependent on run-off, although frequently, as in a well-grassed pasture, considerable run-off of rainfall may occur without serious soil losses [1]. My remarks here are confined also to direct run-off and not spring flow.

Exact quantitative data on this aspect of the subject are meagre. The Mpwapwa soil-erosion and run-off plots [1], dealing with a very dense type of closed deciduous thicket, tend to show that the soil-erosion rate is negligible if the climax vegetation is neither browsed nor grazed. Browsing with goats had the immediate effect of increasing the run-off rate appreciably, although in the small plots in use the erosion rate still remained low. It is probable that if cattle had been used instead of goats, the erosion rate would have increased more markedly, as cattle tend to bare the surface of the ground more effectively than goats. A grazing experiment at Mpwapwa, where the effect of cattle grazing is being studied in secondary thicket vegetation and adjacent "cultivation steppe"[1] plots in which all woody growth is controlled, is of particular interest on this point. Here signs of soil erosion are far more conspicuous in the secondary thicket plots (even with deferred use) in spite of a lower grazing intensity [2].

Extensive observations, which I have been able to make during the past ten years over a wide field in the stock areas of Tanganyika Territory, tend to support the general conclusion that wooded areas are particularly vulnerable to the ravages of soil erosion if they are grazed by cattle. The main reasons for this appear to be: a herbaceous ground vegetation lacking density and composed mainly of annual species; the rapid disappearance in the dry season of the ground cover and leaf-fall with grazing, tramping and termite activities; and the formation of numerous footpaths owing to the tramping caused by the obstructions which the trees and bushes present.

In fairness, I should also point out that the run-off and soil-erosion rates in the Mpwapwa experiments [1] were appreciable in the plots with a purely annual grass and weed cover owing, of course, to the bareness of the ground at the commencement of the rains. A cover composed of a mixture of perennial and annual grasses appears, however, to afford satisfactory protection to the soil. With a rainfall as low as twenty inches per annum in Tanganyika, perennial grasses and herbs (such as *Stylosanthes Bojeri*) tend to form an appreciable part of a bush-free pasture cover even with continuous close grazing. With simple systems of deferred grazing, apparently the perennial species are encouraged greatly [2].

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[1] "Steppe" is hardly the correct word, but for want of a better term "cultivation steppe" is used to denote the open, densely populated areas with scattered trees, often baobabs, and a closely grazed, and often scanty, grass–weed vegetation between the numerous cultivated fields.

Convincing testimony, too, of the value of bush-clearing as an anti-erosion measure is afforded by the extensive clearings at Mpwapwa and Dodoma in the Central Province of Tanganyika, carried out in conjunction with deferred grazing as a reclamation measure on badly eroded land. The same view in regard to "thorn trees" is expressed by a South African worker [3].

Soil Fertility as Affected by Bush Clearing

With shifting cultivation so marked a feature of East African agriculture, the benefits of a spell under regenerating bush in regaining soil fertility are well known to most native tribes. In "cultivation steppe" the benefits of a grass fallow are also well recognized by the cultivators.

In Uganda interesting experiments have been carried out in recent years to determine the effects of a grass ley in restoring soil fertility [4], although, as far as I am aware, a comparison has not been made of the relative efficacy of a bush and a grass ley. The Uganda workers have found that soil fertility under their conditions appears to be primarily dependent on the presence of the physical condition known as "crumb structure". This physical condition apparently is brought about through root contact with the soil particles, and as the root system of a good grass cover probably has a more thorough contact with the soil particles than the root system of any other vegetation type, it may be expected to be particularly effective in this respect. At any rate, Nye in Uganda states: "There is no doubt that it [elephant grass] is an almost perfect regenerator of the soil" [4]. While no other East African experimental data on this point are, as far as I am aware, available, the experience one sees with natural grass leys in "cultivation steppe" areas in Tanganyika offer a good deal of support to the theory. At Mpwapwa there are two experimental acre plots adjacent to each other, the one for ten years under regenerating secondary thicket and the other under a Star grass pasture for the same period. It will be of interest to determine the relative soil fertility of the two plots. When time permits it is hoped to do this.

To sum up, it appears that a grass ley may be equal or even superior to a bush ley (particularly over a period of only a few years) in the restoration of soil fertility following cultivation. The subject is of considerable importance to East African agriculture and would seem to warrant wider investigation than it has received in the past.

Bush Clearing and Stock-carrying Capacity

Attention has been frequently drawn [5] to the benefits which the control of bush may give in regard to the carrying capacity of pastures in East Africa. Some experimental data on this point have also been obtained at Mpwapwa, and it appears that under the conditions there the control of the woody vegetation may increase the carrying capacity of secondary thicket grazing lands no less than four times [2]. In addition to this great increase, the feed produced is better distributed over a longer period of the year, particularly if the growth of the perennial grasses is encouraged by a suitable system of deferred grazing. It is well known that even under temperate conditions and a good rainfall, tree growth reacts unfavourably on a pasture; therefore under conditions where moisture is the all-important factor in vegetative growth, this effect may be expected to be more marked. In East Africa, too, the more valuable pasture species are usually the first to be suppressed by woody growth.

As a means to improve carrying capacity therefore there seems no doubt of the value of bush-clearing even under the more arid conditions in Tanganyika Territory.

Bush Clearing and Water Supplies

To many, the effect of bush-clearing on water supplies is considered both the most important and most interesting aspect of the problem. Gillman [6] has drawn attention to the dominant effect which permanent water supplies have on the distribution of the population in East Africa. In a number of communications [7] [8] [9], I have published preliminary data obtained at Mpwapwa on the effect which vegetation type may have on water supplies under semi-arid conditions in East Africa.

The Mpwapwa work dealing with transpiration and rainfall percolation tends to show that where the vegetation is allowed to grow undisturbed (i.e. is neither grazed, browsed nor burnt) a climax type develops which, under normal Mpwapwa conditions, is capable of consuming the whole of the rainfall normally penetrating into the soil. This appears to apply both to the deciduous thicket vegetation areas at an altitude of 3,500 ft. and to the rather poor type of evergreen forest found at 6,000 ft. on Kiboriani Mountain overlooking Mpwapwa. On the other hand, where the vegetation was controlled and prevented from reaching the climax stage, e.g. by fire, clearing or cultivation, the rainfall was found to percolate more deeply into the soil. In fact, the only proof of part of the rainfall contributing appreciably towards groundwater under a closed vegetation cover (that is, away from rocky outcrops, etc.) was under a grass community on Kiboriani Mountain [10].

A good deal of support to this hypothesis is available from a variety of sources. Confining oneself to East Africa, it is common belief with certain native tribes in East Africa (e.g. the Sukuma) that in dry season waterless areas shallow groundwater supplies appear as a result of cultivation and clearing. Of particular interest is the experience gained in a number of sleeping-sickness concentrations established in Tanganyika Territory. These are all located in *Myombo* (*Brachystegia* woodland) or deciduous thicket areas. The experience here has usually been that shallow well supplies have improved (in certain cases very greatly) following the clearing of the bush and settlement [9].

At Mpwapwa, too, some stream-flow measurements were taken [7] to determine the effects of clearing the evergreen riverine forest on the margins of a small stream at an altitude of 3,500 ft. and in the deciduous thicket formation. The clearing appeared to improve appreciably the stream-flow, particularly during the dry season, when transpiration naturally was at its highest.

Therefore, although further work on the point is desirable, there seems no reason to assume that anti-tsetse clearings in semi-arid East Africa are likely to affect water supplies adversely; in fact, there is some reason to expect that the effects may be beneficial.

Conclusion

In sum, it appears that in the present state of our knowledge bush clearing is not only an effective anti-tsetse measure but it also may be essential if the land is to be made the fullest use of in any system of mixed farming; and opinion gradually appears to be becoming unanimous that the future of semi-arid East Africa lies in some form of mixed farming. By this it is not intended to convey that it will be either necessary or advisable to completely denude the land of tree growth. Trees will be necessary for fuel, for building timbers, for windbreaks and shade, but all these could be provided for in a planned system of land use for each particular area.

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Let us never forget that the cultivation of the earth is the most important labour of man.

Daniel Webster.

He that enlarges his curiosity after the works of nature demonstrably multiplies the inlets to happiness.

Dr. Johnson.

PASTURE MANAGEMENT IN RELATION TO TSETSE RECLAMATION

By **H. E. Hornby, O.B.E., F.R.C.V.S., D.V.S.M., Director of Tsetse Research, Shinyanga, Tanganyika Territory**

Tsetse-flies are widely distributed throughout tropical Africa and as, wherever they occur, stock-raising is difficult or impossible, the full agricultural development of the infested areas is likewise difficult or impossible. This fact is not always fully appreciated in East Africa, where much attention has been focused on soil erosion and on overstocking as a main cause of this evil. There is a tendency to ignore the insistence of agricultural research workers of Lyamungu, Amani, Kingolwira, Mpwapwa, and all other experimental stations which are threatened or already infested by tsetse, that unless these flies are held in check so that cattle continue to be kept it is impossible for soil fertility to be economically maintained. Two things must therefore be considered together:

(1) That crop production, which by itself depletes soil fertility, can, where dovetailed with intelligent animal husbandry practice, be carried on without detriment to the land.

(2) That once the line of conservatism in stock numbers is passed, then the evil effect of overstocking on the soil is likely to far outweigh any benefit the land may derive from the application of manure.

"Tsetse reclamation" is the term now used widely to designate measures to free land from tsetse already present or from imminent threat of invasion by these flies. Its successful practice is based on Liebig's Law of Minimum, which states that "The growth and functioning of an organism is dependent upon the amount of the essential environmental factor presented to it in minimal quantity during the most critical year or years of a climatic cycle". A tsetse population is an organism, and a main aim of tsetse research is recognition of essential environmental factors and ways in which these can be modified.

Up to the present two factors have received main consideration: shade and food-supply. The mobile fly and, still more, the immobile pupa are both susceptible to desiccation and the harmful effect of direct sunlight; so cutting down selected trees and shrubs is an obvious way of reducing the shade factor below the minimum necessary for the tsetse's existence. Blood is the sole food of tsetse; so removal of all sources of blood for even a few weeks would starve out a local fly population. This by itself is not easy, but the opening-up of a piece of country by cutting down trees and shrubs may have a marked effect on a local game population and thereby on the tsetse's main source of food. When this is the case, then clearing which acts detrimentally on the fly in these two ways need not be so thorough as if it had to act through the reduction of shade alone. While, at the present time, tsetse reclamation is practically synonymous with the cutting-down of selected trees and shrubs, the manner and extent of the cutting down should be decided by an expert whose aim is to reduce essential factors to a level below the minimum necessary for the tsetse's survival with the least expenditure of effort.

Tsetse reclamation, then, makes possible the keeping of stock where, before, they could not survive, or removes a threat of stock-extinction from an area. However, the thought of the overstocking which may result from the injudicious use of the reclaimed land is never far from the mind of the conscientious reclamation officer, and it should be an indispensable condition of planned reclamation that subsequent utilization of the land shall be controlled judiciously by some authority. Such stipulations have been introduced in the past, but in few instances have the rules laid down been practised sufficiently consistently to be effective. Far too often, tsetse reclamation has been either so temporary that it was really wasted effort, or it has secured permanent results of freedom from fly combined with soil deterioration.

There are many subsidiary reasons for these failures, but the chief reason is lack of realization that, while temporary reclamation is achieved by cutting down trees and shrubs, permanent and satisfactory reclamation is only brought about through a programme of sustained organized effort, which starts with felling and is continued through a long range of clearing and farming operations until the *whole* of the area is involved in a system of agricultural development which simply does not allow tsetse to exist; since no part nor phase provides the fly's requirements of shade, food and security from capture by man.

An essential part of this system is the development in the mind of the native (and of many Europeans) of a new conception regarding pasture. He must begin to realize that animal products are no more to be obtained without labour than are plant products, and that to obtain meat, milk, skins or work from his animals he must *provide* these with pasture. That is, pasture must be looked upon as a crop demanding labour for its management, in the way that a crop of millet or rice demands it. It is true that at first sight nature does appear to provide grass for cattle for the picking-up, but very little examination of the facts shows that this picking-up is an agricultural operation which may favour, or may damage and even destroy the plants that are grazed. Only good methods of management can ensure maintenance of pastures; that is, of utilized grasslands; and, since the essence of much tsetse reclamation is the substitution of grasslands for woodlands, on the maintenance of pastures may depend both the value and the permanence of the clearing.

In America, prairie is considered a true climax, and it may be that the large short-grass plains of Athi, Ardai and Serengeti are also climax; though this is very doubtful. What is certain is that the bulk of the grasslands of East Africa are seral communities successional to woodlands. Some are maintained through seasonal flooding, but most are maintained through fire. The effects of grazing on these fire-maintained grasslands depend on its intensity: if it be light enough to permit occasional strong fires, then the browsing of transitional shrubs that always accompanies grazing may help to stabilize the grassland stage; once, however, grazing is heavy enough to abolish fires then it always causes more severe setback to the grasses than to the shrubs, and the succession tends to advance to a transitional shrub stage, and thence along the road towards development of a woodland climax devoid of ground herbage. The aim of the pastoralist is the maintenance of open grassland—a form of vegetation which, by itself, cannot support any species of tsetse.

It follows from the above considerations that the usual native (and European) method of herding stock is one that is likely to lead to disaster. The owner turns his animals into open thicket and savanna and expects them to get their living there. If the numbers are more than a few, the usual results are that the bush gets thicker, carrying-capacity is lowered, soil erosion is engendered, danger from vermin and theft increases and, in certain conditions, encroachment by tsetse is encouraged. If encroachment does occur under these conditions, it is not an altogether bad thing, since it puts a stop to serious range mismanagement. Look at much of the recent fly-encroachment in the Central Province: one sees there a poor type of *miombo* wooding that in the absence of stock is kept open and in a state of disclimax by recurrent fires. The soil is sandy, easily eroded, and consequently very susceptible to damage by stock; in fact, this kind of country can hardly be grazed at all without sustaining damage; in other words, the line of conservatism in stock numbers, beyond which stock do more harm than good, is easily passed. Hence the encroachment of tsetse was not an unmitigated evil.

One of the tasks of the Tsetse Research Department is to study fly advances and to, at any rate, warn administrators and occupiers of threatened areas of the danger. By many it is believed that it is also the duty of the department to do something about stopping these advances. I admit to little enthusiasm for barrier-clearings so long as the majority of stockowners show little sense of responsibility for soil conservation. I incline to the belief that if the threat of tsetse is necessary to inaugurate better methods of stock management, then this threat is a good thing. As tsetse reclamation in its broad sense includes good farming, which in turn requires the substitution of pasture for much of the woodland, an inference is that it is the good farming which holds the land against reinfestation. Hence large areas which are wholly well farmed need little protection. On the other hand, small scattered holdings, however well farmed they are individually, will suffer from fly-encroachment. Were barriers practicable, their formation for the protection of a large number of such well-farmed holdings would certainly demand consideration. But I know of no such community; almost invariably the population to be protected are not good farmers. The standard of animal husbandry among native stockowners is very low, and raising this standard is an important form of protection against tsetse.

The Government farms at Mpwapwa furnish a good example of protection obtained in this way. There are now two veterinary farms: (*a*) a small dairy farm of 300 acres on the much cultivated Ugogo plain, and (*b*) the much larger laboratory farm two miles further north and within a cup of high hills.

When, after the last war, work was first started at the laboratory in 1920, there was really no farm at all, and for some years the cattle used for serum production were turned into thicket and forest to graze—exactly as natives treat their animals. The vegetation of the valley is deciduous scrub that gives way, at about 3,500 ft., to a *Combretum* interzone, which, in turn, above 4,000 ft., is replaced by *Brachystegia-Isoberlinia* (*miombo*) communities. At the top of the highest hills is evergreen forest climax and pro-climax, and running down the hillsides and for a little way on to the plains are broad lines of evergreen fringing forest. During those early years of stock mismanagement the laboratory animals obtained most of their food from the assorted grasses of the lower *miombo*. (An excellent photo of this community is Plate VI of Greenway's article on the vegetation of Mpwapwa that appeared in the *Journal of Ecology*, 1933, Vol. XXI, pp. 28-43.) To get to this grazing the cattle had to travel through thicket, where they got some browse but no grazing, and through the *Combretum* interzone, where they picked up a few grasses, chiefly annuals. Although the "farm" was more than 2,000 acres in size, the three or four hundred head of laboratory cattle would have starved at the end of each dry season had they not been sent to a similar overflow "farm" at Tubugwe, lying beyond the eastern boundary of the laboratory one. It was at Tubugwe, about 1924, that the first cases of trypanosomiasis contracted locally by laboratory animals were diagnosed. In 1927, there were more than 60 fresh cases, contracted for the most part at Tubugwe. By 1932 it was recognized that infection was being contracted on the laboratory farm as well as at Tubugwe, and no herd seemed safe, not even those of the dairy farm, since these came to the laboratory to be dipped. Meanwhile, although the substitution of thicket by grass paddocks was proceeding, there was still much exploitation of *miombo* grazing. This was causing thickening of the woodland portion of the now unburnt savanna and marked erosion of all hillside approaches to the grazing-grounds. A position was reached not unlike many to be found all over the Territory at this moment; wherever, in fact, areas eroded from overgrazing are threatened by tsetse.

Tubugwe had to be abandoned, but it was hoped that the tsetse (*G. pallidipes*) of the laboratory farm were not established there, and so a barrier-clearing was interposed between this farm and the known permanent haunts of tsetse a few miles to the west (*see* Swynnerton's *The Tsetse Flies of East Africa*, p. 379). This appeared to achieve a temporary success, but later it was found that tsetse were actually established inside the barrier, on the laboratory farm itself, and fresh cases of trypanosomiasis continued to occur.

It is certain that the pasture investigations at Mpwapwa — which, from 1930, were a prominent feature of research—would have led inevitably to cessation of exploitation of the local hillside woodland grazing, but the knowledge that somewhere among the thicket and trees there lurked tsetse undoubtedly speeded up the work of making the laboratory animals entirely independent of woodland grazing. It is only quite recently that planting of the whole clearing of about 800 acres, hewn entirely out of thicket and *Combretum* woodland, has been completed. In 1920 this same area could not have carried 100 cattle without seasonal starvation and at the expense of some erosion. To-day it is estimated that 350 head can be fed entirely from the clearing without causing any damage at all. Of course, persistent slashing of coppicing and suckering stumps and other weeding are necessary for the maintenance of the pasture, but the labour is well worth while; an almost worthless jungle has been transformed into a valuable farm. The clearing is by no means devoid of trees. There are still many, scattered everywhere and defining the watercourses, but nowhere are they close enough together to spoil the excellent and continuous grass cover. *Cynodon plectostachyum* is the grass chiefly planted, but there are many other species as well. Of the details of clearing, contour-banking and planting I do not wish to write, but I can testify to the effect of keeping the herds out of the woodland, on their general condition, which is much improved, and, above all, on the incidence of trypanosomiasis.

As clearing progressed, the first herds to be kept from all woodland grazing were the breeding animals, and from this time, in 1938, until now (April, 1941) no fresh cases of trypanosomiasis have been diagnosed among them. In the herds of oxen that were still forced to leave the cleared area for some of their grazing, cases continued to occur, but as the herds were withdrawn more and more completely into the clearing the occurrence of fresh cases declined, and has been nil for the last four months. The perimeter of the clearing —a wall of thicket—is patrolled by fly-boys using a bait ox, and a somewhat surprising result is that during the last three months they have not only failed to catch a single tsetse on this round but excursions into likely places outside the clearing have also yielded persistently negative results. It would be premature to say that all danger of trypanosomiasis had been removed from the laboratory farms, but the situation must be regarded as most satisfactory.

I have said that pasture investigations alone, without the need to avoid tsetse, would have led to cessation of exploitation of hillside woodland grazings at Mpwapwa. Indeed, a lesson that pasture research is teaching everywhere is that no woodland furnishes satisfactory grazing, since any stocking, other than the very lightest, of such land is bound to cause diminution of carrying capacity, and may easily cause soil erosion as well. Yet on the majority of European-owned farms away from open grasslands cattle are often out of sight from the time they leave their kraal in the morning, and owners complain that grazing is deficient, that their animals are liable to be lost or stolen, or to be taken by lions, or to contract disease from trespassing native-owned cattle. Ten or more acres of even excellent land under these conditions may be required for one beast, whereas clearing and planting the same land might yield pasture capable of carrying a beast to two acres the whole year round under conditions where they could be watched and safeguarded from theft, vermin and disease. The development, then, of a system of pasturing cattle more and more on artificially created grassland is a measure that is necessary when tsetse are about, and is highly desirable even in the absence of fly.

So far I have dealt with the work of the pasture officer in connexion with that of tsetse reclamation as though his work consisted entirely in creating and maintaining permanent pasture. As very large numbers of cattle belong to people who do no hoeing, this emphasis is understandable. However, there are also large numbers of cattle which feed on arable land after the harvests are reaped, and again on the same land during the years between its release from crops and the time when it is claimed by thicket, the regrowth of which is often associated with fly encroachment. It would be an excellent thing from the view of protection from tsetse and, I think, from the view of good agricultural practice, if laid-down grass was substituted for thicket in crop rotations. Such a development would require much guidance from pasture officers.

The existence of sleeping sickness in a district necessitates the separation of the human population from contact with tsetse, and large clearings have been made to permit this. In these "sleeping-sickness settlements" regrowth of thicket is a constant menace; it forms a mosaic of potential fly-bush between the cultivated fields which may link with the adjoining fly-infested woodland. When stock are absent, not only is maintenance of fertility of these settlements a difficult problem, but the continual slashing of bush on unused land seems a dreary and unprofitable task. For the full success of these concentration schemes the following rules should be observed:—

(1) Reduce the proportion of periphery to area to a minimum by making each clearing as large as possible, consistent with proper maintenance, and making the outline as near to a circle as possible.

(2) Encourage the right amount of stock-keeping (*a*) for nutrition of the people, (*b*) as a source of true wealth, (*c*) for maintenance of soil fertility, and (*d*) that land lying between cultivated fields may be fully utilized.

(3) Define the perimeter very sharply. It should stand as a wall of thicket or forest, separating open grassland from woodland.

(4) Leave a few fine trees for shade throughout the whole clearing, and leave "islands" of woodland within all settlements which are sufficiently large to accommodate these a mile or more away from the perimeter. They furnish poles and firewood, and should be grazed conservatively.

(5) Discourage people and their stock from passing into and out of the settlement except along defined paths, which can be picketed to prevent carriage of flies.

(6) Discourage movements of game of all species into the settlement.

(7) Arrange for fly-boys to search continually for tsetse along the periphery, and when any sector shows more than the lightest concentration this should receive special attention with the aim of reducing fly numbers.

Again we meet with a measure necessary on account of trypanosomiasis—in this case, human as well as animal—that is likewise desirable in the interests of good agriculture and effective vermin control. I see no good reason why this settlement system—in which there is no place for unnecessary shifting cultivation and soil erosion, and in which stock play an important and wholly salutary part—

should not be extended to every part of Tanganyika Territory. Thus this country would come to be sharply divided into (1) man-and-stock areas free from tsetse and in which game are not protected by law, and (2) game-and-fly areas, used as little as possible for agriculture, where game are adequately protected. The settlements would be of varied size above a minimum. As more land was required by one of them, it would be taken in an orderly fashion by pushing any part of the perimeter that was not adjacent to a national park further into the fly-bush. Such extensions would lead to coalescence of settlements; with further proportionate reduction of perimeter measurements, and wider facilities for the movement of men and stock without the need for their coming into contact with fly at all.

Orderly settlement and farm management on these lines would go far to meet the tsetse menace throughout East Africa. But as long as tsetse persist around the protected settlements, serious inconveniences will remain, constant extra work and vigilance will be needed, and free movement of stock for sale or transfer will be difficult or impossible. Long-range research directed to remove the flies from the unoccupied woodland around the settlement continues, and should do so. It has yet to produce definitive results of wide application. Meanwhile, rigid definition and intelligent management of the settled areas should form the basis of our present farming policy.

The development of this policy would demand the co-operation of many departments, and would afford full expression of the intimate relationship of pasture management to tsetse reclamation.

Summary

Although overstocking is the source of much soil erosion, this must not blind people to the fact that live stock, in correct concentration, are necessary for the full agricultural development of any area. Tsetse reclamation is thus a necessary agricultural measure.

The usual method of reclaiming land from tsetse involves clearing of some kind, the purpose of which is the reduction of factors essential for tsetse to below the minimum necessary for the fly's survival.

Much of the failure of reclamation work in the past is due to lack of realization that reclamation is not effected by any sporadic or seasonal effort, but by a long series of sustained clearing and farming operations involving the whole of the area, and demanding acceptance of the idea that pasture is a crop requiring labour for its maintenance.

The need for this labour is inherent in the nature of most grasslands. Ordinarily these are fire-maintained, and when converted into pasture, and fire excluded, they can be maintained only with the assistance of weeding. Uncontrolled grazing leads inevitably to lowered carrying capacity and frequently to soil erosion. In this case, fly encroachment, which will slow down or abolish the soil erosion, may not be a bad thing. For this reason, barrier clearings for the sole purpose of protecting areas from fly may not be justified while the areas are as badly farmed as many are at present.

Merely raising the standard of animal husbandry constitutes an important form of protection against tsetse. A good example of this is furnished by the veterinary department's farms at Mpwapwa, where trypanosomiasis was a scourge of the herds as long as these were allowed to search for their food in woodlands, but which ceased to be a serious trouble when the grazing area was cleared of thicket and planted with grass. At the same time the carrying capacity of this area was raised many times by the reclamation. The development of a system of pasturing cattle more and more on artificially created grassland is a measure that is necessary when tsetse are about, and highly desirable even in the absence of fly.

A plea is made for such extension of the "sleeping-sickness settlements" scheme that the whole of Tanganyika Territory would become divided sharply into (1) man-and-stock areas, free from tsetse and in which game are not protected by law, and (2) game-and-tsetse areas, used as little as possible for agriculture, where game are adequately protected. The development of this policy would afford full expression of the intimate relationship of pasture management to tsetse reclamation.

At the same time, long-range research directed to remove the flies from the unoccupied woodland around the settlements continues, and should do so.

(*Received for publication on* 30*th April,* 1941)

NOTES ON PLANT DISEASES

By **R. M. Nattrass, Department of Agriculture, Kenya**

1—The White Mould of Napier Grass

Napier grass (*Pennisetum purpureum*) is frequently seen, especially during the rains, to be covered on the lower surface of the leaves, and also to a lesser extent on the upper surface, with numbers of small raised white pustules of a snow or cottony-like texture. Individual pustules vary in size from ½ to 2mm. in diameter, and may be up to 1 mm. in height. When viewed with a pocket lens they appear to have a faint pinkish tinge. The pustules may occur either singly or more often in line, each group lying parallel with the midrib. There may be as many as eight or ten, decreasing in size from the centre. On the opposite surface of the leaf the position of a group of pustules is indicated by a lenticular-shaped spot which, according to age, may be light green or yellow or consist of dry pale tissue surrounded by a purple margin, and which, superficially, resembles spots caused by the fungus genus *Helminthosporium.*

The white mould is the fructifying part of the fungus *Beniowskia sphaeroidea.* It is common throughout East Africa, where it readily attacks both varieties of Napier grass and less frequently certain other grasses, including Kikuyu grass (*Pennisetum clandestinum*).

The effect of the fungus on the grass is very localized, and moderate attacks appear to have little effect on the vigour of the plant. When the crop is very heavily attacked there may be browning of the leaves from the tips, and it may then be advisable to cut down the growth before excessive drying takes place. As far as is known, the feeding of diseased leaves has no harmful effect on stock.

2—The Black Heart Disease of Potato Tubers

It is occasionally found that on cutting potato tubers the flesh, especially in the centre, is discoloured dark grey or even black, and appears to have a rubbery consistency. The discoloration does not always extend to the surface of the tuber or may do so at one point only. It is therefore not always disclosed by peeling.

This condition is a physiological disease known as "black heart", and is induced by a deficiency of oxygen. It usually occurs during storage, when the respiration of the tubers raises the temperature and at the same time reduces the supply of oxygen. Immature tubers under bad storage conditions are especially liable to suffer in this way. The recent heavy losses in shipments of potatoes from South Africa can probably be attributed in the first place to this disease. Immature tubers may also be affected even in the open air if they are exposed to temperatures of 38° C. and over. Care should therefore be taken when lifting potatoes, especially if immature, as is likely to occur when there is a shortage, to ensure that they are not exposed to the direct effect of the sun. Conditions of storage and transit are of special importance in hot climates. Care should always be taken to ensure that adequate ventilation, even for short periods, is provided, especially if the crop has not been allowed to mature fully below ground.

Some varieties are more susceptible than others; Tinwald Perfection and Duke of York are resistant, while Majestic is very susceptible. The popularity of the Italian white potato on the Indian market is largely due to its resistance to the effect of high temperature. A trial carried out in the Poona district with this and eight English varieties showed that the Italian was much more resistant to heat and infection in that climate.

A similar blackening of the flesh may also be brought about by other causes, particularly bruising.

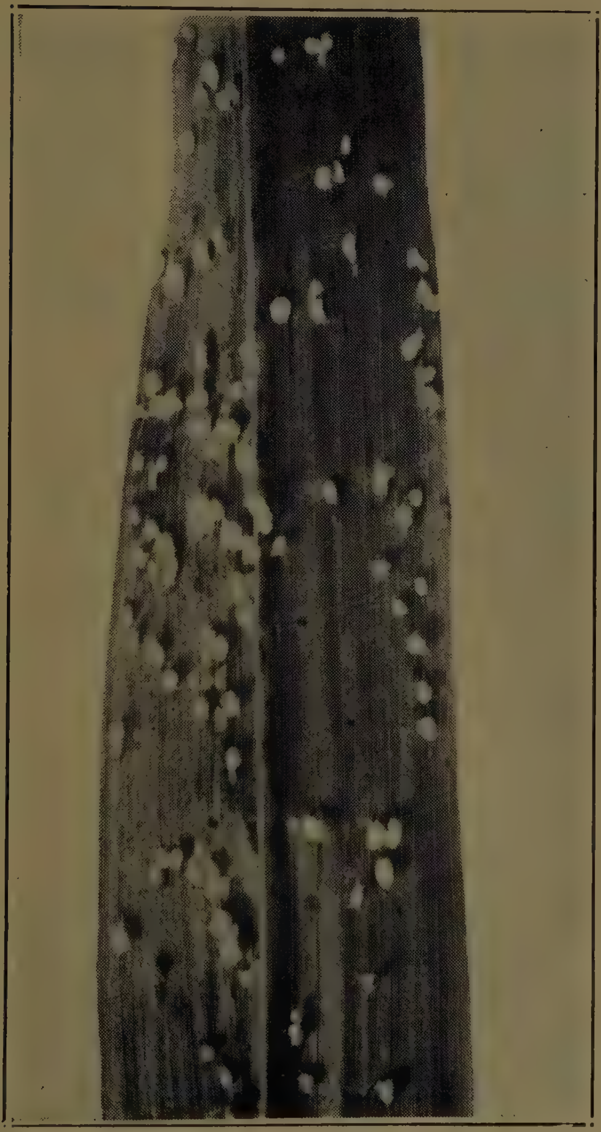
Affected tubers should not be planted, as they will either fail to sprout or will produce only weak plants.

(*Received for publication on 28th January*, 1941)

In the application of the results of experimental studies carried out at Mpwapwa on soil conservation and reclamation of advanced erosion areas, the Tanganyika Veterinary Department was mainly concerned with efforts to introduce simple deferred grazing systems into native practice. Good progress was achieved, and as the result of preliminary demonstration trials and propaganda it was estimated that some quarter of a million acres in the Central Province alone would be in partial or complete reserve early in 1940. In the Sukuma area of the Lake Province, the aggregate effective reserves totalled some 150,000 acres, and the results were so spectacular that the chiefs and people were enthusiastic in their praise.

Annual Report of the Department of Veterinary Science and Animal Husbandry for the year 1939.

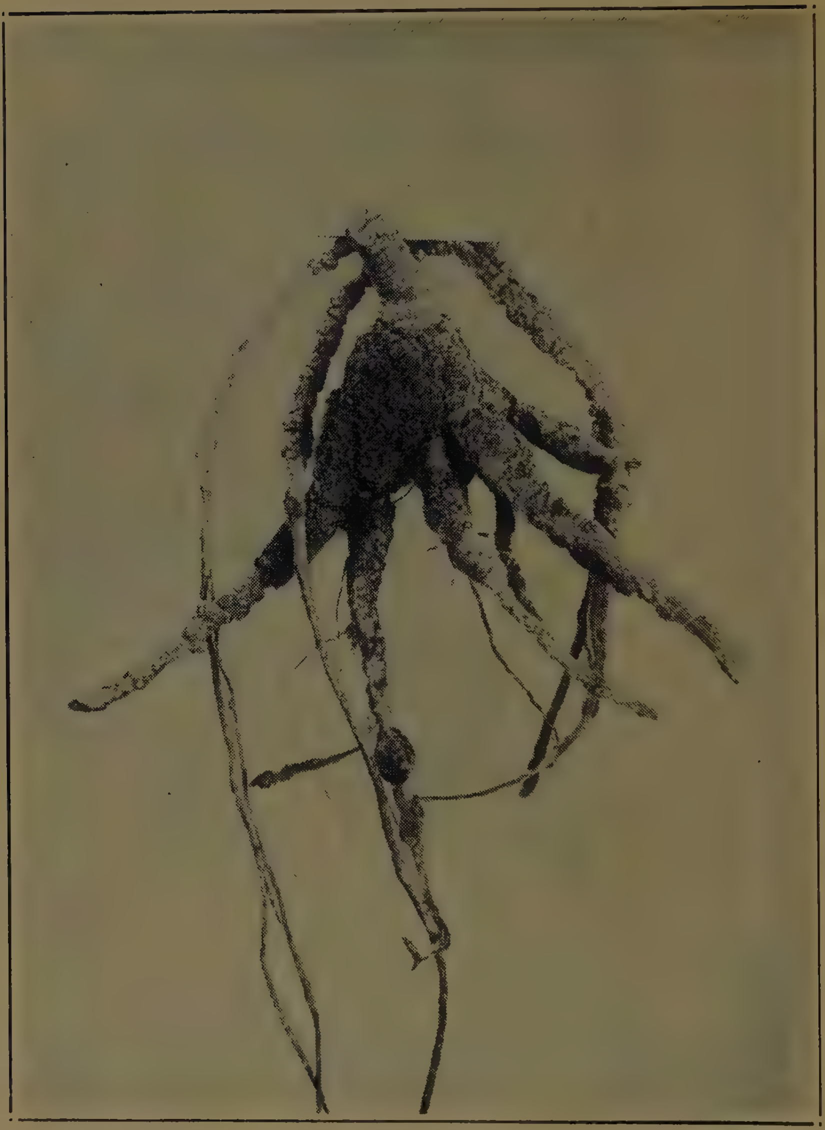
WHITE MOULD OF NAPIER GRASS



Beniowskia sphaeroidea on leaf of Napier grass
× 2½ approx.

[*Opposite page* 56

NEMATODE ON OYSTER NUT



Root of two-year-old plant, × 1/20 approx.

(Readers of the note on Nematode Disease of Oyster nut in the October, 1940, number of the Journal may be interested to see this photograph of the effect of the nematodes on a two-year-old plant.—R.M.N.)

PLANT DISEASES IN KENYA DURING 1940

By R. M. Nattrass, Department of Agriculture, Kenya

The following plant diseases are believed to be new records for Kenya:—

Macrosporium carotae Ellis and Langlois.

A single outbreak of this disease on carrots occurred in the Sotik district. The fungus, which affects only the leaves and petioles, causes numerous small lesions, turning the plants yellow and finally black and shrivelled.

The fungus agrees with the description and figure of *Macrosporium carotae* Ellis and Langlois, in Meier, Drechsler and Eddy, *Phytopath*, 12, 157, 1922. It does not differ greatly from the long-beaked *Alternarias* of the *Solani-Macrospora* group. The spores without beak measure 37-75 x 15-16 microns and with beak up to 225 microns. Similar filiform processes are frequently produced at the apex of the conridiophore after the terminal spore has fallen away.

This disease, which occurs on the American Continent, Bermuda and Australia, does not appear to have been recorded from East or South Africa. A leaf blight caused by *Alternaria Brassicae* (Berk.) Sac. has, however, been recorded from South Africa and Rhodesia.

Elsinoe phaseoli Jenkins.

This fungus appeared for the first time in Kenya on a crop of green gram (*Phaseolus aureus*). The effect on the crop was serious, leaves, stems and pods being affected. The lesions are greyish-white to a vinaceous buff; the *Sphaceloma* stage being usually of the former colour. The lesions occurred either separately up to 1 cm. in length or coalesced, covering large areas of the plant. Young pods were frequently entirely covered. Seriously affected pods were curled and petioles thickened and distorted.

The Imperial Mycological Institute reported "the Kenya specimens agreed very well in appearance with those of *E. canavalii*, of which *E. phaseoli* is a segregate. The asci and ascospores in both are the same."

The affected crop was destroyed as far as possible and a small area was again planted experimentally the following season. These plants were also attacked by the disease.

Ascochyta caricae Pat.

The fungi usually responsible for rot of pawpaw fruit are *Gloeosporium* and *Collectotrichum* (*Glomerella cingulata*), and are present to a greater or lesser extent in all plantations. In one plantation, however, a black leathery rot was caused by *Ascochyta caricae* Pat., and was readily reproduced by inoculation with pure culture. The rot is distinguished from that caused by *Gloeosporium* by the closely aggregated pycnidia from which, under moist conditions, white spore tendrils protrude. The spores are mostly two-celled with one cell often larger than the other. They measure 8-11 x 3-4 microns. Many of the pycnidia contain only single-celled spores and would thus be referred to *Phoma*, but typical Ascochyta spores develop later.

Phleospora on *Stapeliads*.

A serious disease affecting many of the succulent *Stapeliads* occurred in the Nairobi district during March and April. The disease starts as a small very deeply sunken lesion, the bottom of the cavity being covered with numerous pycnidia. The lesions which may be up to 1 cm. in diameter quickly become confluent and the aerial parts of the plant black and shrivelled.

The pycnidia are caespitose, without stroma and are completely immersed. They are about 150 x 125 microns in diameter and are more or less broadly open at maturity. The spores are 40-60 x 3-4 microns, and 1-2 septate. Although the walls of the pycnidium are thicker and more developed than in the usual conception of the genus *Phleospora*, from the general habit on spot lesions and shape of the spores it conforms more to this genus than either *Septoria* or *Rhabdospora*. It is considered to be an undescribed species of *Phleospora*.

Phomopsis sp. of Lavender.

A high proportion of dieback and crown rot in a commercial planting of lavender was found to be associated with a species of *Phomopsis*, which could without difficulty be obtained in pure culture from recently invaded tissue. The primary cause of the disease is thought to be the splitting of the crown and main branches, to which, with the present system of cultivation, the lavender is very subject.

Melanospora parasitica Tul. occurred on *Cephalosporium* sp. attacking coffee mealy bug (*Pseudococcus kenyae*).

Oidiopsis taurica was recorded as causing a leaf spot of *Tropaeolum* in gardens, and *Verticillium dahliae* Kleb. a wilt of egg plant.

During the year a further physiologic race of wheat stem rust, K6, has made its appearance, first on Reliance, which hitherto has been susceptible to K3 only.

(*Received for publication on 29th April, 1941*)

NOTES ON ANIMAL DISEASES

XI—VIRUS DISEASES OF PIGS

Compiled by the Veterinary Department, Kabete, Kenya

African Swine Fever

African swine fever is a highly contagious and very fatal disease of pigs caused by a filtrable virus. The disease causes lesions very similar to those of classical swine fever of Europe and America, but the virus differs in one important feature from classical swine fever virus. The latter virus is antigenically stable; a pig that has recovered during an outbreak of swine fever in Europe will resist infection by other strains of virus. Virus collected from local cases is, however, remarkably unstable. A pig that has recovered from African swine fever may be reinfected with the same strain of virus after it has been subjected to a few further passages in pigs. Possibly the classical strain has been derived from a virus of wild pigs by repeated passage in domestic pigs.

The virus of African swine fever can be preserved for a period of two years or more if infective blood is collected in citrate or O.C.G. solution and stored in the dark. The virus soon loses its infectivity, however, under natural conditions, particularly when exposed to sunlight, and infection generally disappears from a sty fourteen days after the last death. After death the virus is present in the blood and hence in all the organs of the body. The disease is directly contagious, and infection is easily conveyed from sty to sty by litter, food, the feet of attendants, etc., contaminated with excreta from infected pigs. Once swine fever appears on a farm it is extremely difficult to prevent it spreading to all the pigs on the premises. In the majority of outbreaks it is not possible to state how the virus has been introduced in the first instance.

Animals susceptible.—The domestic pig is highly susceptible. In the wart-hog the inoculation of infective blood produces little or no evidence of infection; but after a normal incubation period the virus can be recovered for some time from the blood. It is thought that the wart-hog may be responsible for the introduction of the disease to clean farms, a theory supported by epizootiological evidence in Kenya. Occasionally wart-hog taken wild are found to harbour the virus in their blood. In order to explain spread of the virus from wart-hogs to pigs, it has been suggested that the virus is transmitted by a blood-sucking insect, for contact between the two is never very close.

On inoculation the bush pig behaves in the same way as the wart-hog.

The horse, ox, sheep, goat, dog, etc., show no ill-effects on inoculation with virus, and small experimental animals likewise give no evidence of infection.

Incubation period.—In pigs exposed to contact infection, the first rise in temperature occurs in about seven to twelve days, whereas after the inoculation of infective blood the reaction commences about the third day, sometimes even earlier.

Symptoms.—There is a sharp rise of temperature, reaching maybe 105° F. or over. The temperature remains elevated throughout the course of the disease, but may drop suddenly before death. There is dullness and a disinclination to feed; the animal lies huddled under the bedding, and the respirations become accelerated and jerky. If standing, it stands with back arched. There may be a swaying movement of the hind part of the body. In some cases the hind legs appear paralysed and muscular body tremors and inability to rise may be present in the later stages. The fæces are occasionally coated with blood. Reddening of the skin of the hairless parts, such as inside the forearm, the lower part of the abdomen, the inside of the thigh, and under the jaw, is sometimes observed.

Unless the animals are under very close observation the first indication of an outbreak is the discovery of one or two dead pigs, while a number of others are obviously sick.

Although sometimes it is earlier, death usually occurs in from about four to five days after the commencement of the temperature reaction.

Post-mortem lesions.—The characteristic "button" ulcers in the cæcum and anterior portion of the large intestine which occur in classical swine fever are not a feature of the African disease.

The common lesions are an enlarged and softened spleen, a reddening of the mucous membrane of the stomach and hæmorrhages on the outer wall of the heart and on the lining of the heart cavities. In a percentage of cases the following additional lesions are found: a spotted turkey-egg-like appearance or a diffuse reddening of the kidneys; small pin-point hæmorrhages or a diffuse reddening on the outside of the wall of the intestines and an acute hyperæmia and œdema of the lungs with foam in the bronchi. In advanced cases it is usual to find blood extravasations on the mucous membrane of the intestine, in which case the contents are coated with blood. The mesenteric and body lymphatic glands are invariably hœmorrhagic.

Diagnosis.—Generally speaking, the diagnosis can be supported by the history of the outbreak and an examination of the in-contacts. In cases where the lesions are masked by post-mortem changes and there is doubt, the diagnosis can be confirmed if a sample of blood in preservative is submitted for biological test.

Mortality.—Mortality is very high, and it is rare for a single pig to survive an outbreak.

Treatment.—There is no known medicinal agent that can be used to influence the course of the disease.

Attempts to produce a hyperimmune serum and vaccine have been made at Kabete repeatedly. Such products, to protect against one strain of virus, can be obtained, but they are of no value in the field owing to the antigenic lability of the virus.

Where the stock is of great value and the disposition of the buildings on a farm allows, the control of the disease by quarantine may be attempted. Segregation of the healthy from the diseased pigs, thorough disinfection of the infected sties and utensils, slaughter of affected pigs, and burning of infected carcasses and litter should be carried out, and the sty left vacant for fourteen days after the last death, or fourteen days after recovery of the last case. The early morning temperature (8 a.m. or thereabouts) of all pigs should be taken, and those with a normal temperature should be separated in a clean sty away from the infected sties. The temperature of the pigs which have been removed to the clean sty should be taken for a further fourteen days, which more than covers the average incubation period from natural infection. Should any show a high temperature during this period they should be immediately removed from the sties and destroyed, and the temperatures of the remaining pigs taken daily for fourteen days after the last case. If the animals which are removed to the clean sties run a normal temperature for fourteen days after removal they may be considered non-infected. The attendants of the pigs which are removed to the clean sties should not be allowed access to infected sties, and in taking the temperatures the thermometer should be disinfected after each temperature has been taken in order to avoid transmitting the disease from one pig to another through the medium of the thermometer.

Generally, however, owing to the extremely contagious nature of the disease, a slaughter policy is recommended. The pigs should be killed and, after thorough cleaning and disinfection, the sties should be left for at least fourteen days before restocking.

SWINE INFLUENZA

During the last great pandemic of human influenza, which covered the years 1918 and 1919, certain North American veterinarians recorded the appearance of an unusual form of pneumonia in swine. The pneumonia appeared to start in the anterior lobes of the lung, and in fatal cases it was remarkable chiefly for its intensely œdematous nature, the whole lung having a waterlogged appearance. Although fatal cases of pneumonia generally amounted to some 4 to 10 per cent of the herd, the whole herd was usually attacked by a sudden febrile illness, characterized by a cough, extreme prostration, lack of appetite, laboured abdominal respiration, and acute muscular pain or tenderness. The duration of the illness was short, varying from two to six days, and in all but the pneumonia cases recovery was as rapid as the onset. Colloquially the disease became known in America as "hog flu", from its resemblance to human influenza.

It was not until 1932 that the brilliant investigations of Shope demonstrated that the disease was in reality an influenza; that a bacillus closely related to the so-called influenza bacillus of man was invariably present in severe cases, and that the primary cause of the disease was a filtrable virus, which was only capable of infecting pigs when it gained direct access to the lungs through the nasal passages. Following this lead, workers in England and America were able, in 1934, to prove that human influenza was also a virus disease, and that certain strains of the human influenza virus, including that of the 1918 pandemic, were related to, though distinct from, the virus of swine influenza. Meanwhile, in Germany, attention had been drawn to the possibility that contagious pneumonia of piglets, which annually caused considerable loss to pig owners, might be a form of swine influenza, and although it proved difficult to demonstrate the presence of the virus in these cases, the swine influenza bacillus was easily isolated.

The first appearance of the disease in Kenya seems to have been in 1935. The laboratory was consulted concerning an alarming outbreak of a highly contagious disease among the pigs on a farm in the Elburgon district. More than 90 per cent of the pigs on the infected farm were affected by the disease, which was characterized by coughing, stiffness of the muscles and joints, and extreme prostration. Animals were sent to the Laboratory for diagnosis, and on post-mortem examination they proved to have the lung lesions typical of mild cases of swine influenza as described in America by Shope. There was no actual pneumonia in most of the animals, and the lesions were confined to the collapse of large portions of the lung in the anterior lobes. The tentative diagnosis of swine influenza was confirmed by the rapid recovery of the great majority of pigs on the infected farm, mortality amounting to less than 2 per cent. Since swine influenza of the American type affecting adult pigs had not been recorded anywhere outside North America, experimental work was undertaken to confirm the diagnosis and to identify the virus if one could be recovered. The disease proved to be readily transmissible by intra-nasal inoculation, and there was no difficulty in reproducing the characteristic lesions of the mild form of the disease by intra-nasal inoculation of filtrates. Bacteriological investigation of the lungs of infected animals resulted in the isolation of numerous strains of the influenza bacillus, at times in pure culture and at other times in association with other organisms. When inoculated alone, the isolated bacteria proved to be devoid of pathogenic power, but when mixed with the virus a mild infection with characteristic lung changes was produced.

A few months later it became evident that the disease had spread widely throughout the Colony. At times almost every pig that arrived at the Nairobi Abattoir would be found to have lesions in the lungs, and on several occasions more than 80 per cent of the lungs of pigs slaughtered during one week would be condemned for pneumonic lesions of the swine influenza type. Virus was recovered several times from such material collected at the Nairobi Abattoir, and the influenza bacillus was isolated repeatedly.

Later in the year, also, the attention of the Laboratory was drawn to a farm where extremely heavy losses had been occurring for some type among sucking-pigs. Over a period of some months the mortality in litters had exceeded 70 per cent. Examination of affected piglets revealed the characteristic lesions of "piglet influenza" of the German writers, and again it was possible at Kabete to isolate the virus from this infection and to transmit the disease by combined intra-nasal inoculation of the influenza bacillus, which was also present, and the isolated virus. When transmitted to larger pigs, the virus from the piglet influenza gave rise to the mild infection characteristic of the typical American swine influenza outbreak. The disease is highly contagious, and experiments at the Laboratory were considerably hampered by the lack of suitable isolation accommodation.

Although, from the Kabete experience, it seemed clear that the ordinary swine influenza and the piglet influenza are caused by the same combination of virus and bacterium, piglet influenza, in striking contrast to the other form, is usually responsible for an extremely heavy mortality on an infected farm, and whereas with the ordinary swine influenza the disease passes with extreme rapidity through all the pigs on the premises and then disappears, it is usual, with piglet influenza, for losses to be spread over many months or even years.

With regard to treatment and prophylaxis, neither is of much value in dealing with the epizootic type of the disease, but with the enzootic piglet influenza attention to the sanitary conditions under which sows are farrowed and rear their young will usually effect a prompt improvement in the mortality rate of piglets. In Germany, where piglet influenza causes serious losses each year, farmers whose herds are infected are advised to isolate their farrowing sows individually, and special straw huts for farrowing are constructed in the fields. The sows farrow in these individual straw huts, and the young pigs are retained in a small run with their mother until they reach the age of eight weeks. There is some indication, from experiments at Kabete, that inoculation of young pigs with a vaccine prepared from a formalinized lung containing virus is of help in controlling the incidence of piglet influenza, but there is no doubt of the success that attends a careful application of the method of individual isolation of farrowing sows in well-ventilated temporary huts.

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